Defense Technology Area Plan

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OFFICE OF THE DIRECTOR OF
DEFENSE RESEARCH AND ENGINEERING

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The Defense Technology Area Plan (DTAP) is issued by the Director of Defense Research and Engineering (DDR&E) to guide the Department's Applied Research (6.2) and Advanced Technology Development (6.3) investment decisions.

This edition of the DTAP has been prepared by the ten Defense S&T Reliance panels overseen by us, the Reliance Executive Committee. This Plan documents our vision, strategy, goals, Defense Technology Objectives (DTOs) and technology roadmaps being pursued during the FY97 budget and Future Years Defense Plan. The DTAP also identifies the funding allocated for DTOs and the Fiscal Year when these technologies may be transitioned to development to create new warfighting capabilities.

The DTAP provides a means to communicate our objectives and work to our customers: the development community, warfighters, and Congress. Adherence to this DTAP will ensure that the Department's investment in S&T is responsive to our customers, properly focused, affordable, and well executed.

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INTRODUCTION AND EXECUTIVE SUMMARY

Since World War II, owning the technology advantage has been a cornerstone of our national military strategy. Technologies like radar, jet engines, nuclear weapons, night vision, Global Positioning System, smart weapons, and stealth have changed warfare dramatically. Today's technological edge allows us to prevail across the broad spectrum of conflict decisively and with relatively low casualties. Maintaining this technological edge has become even more important as the size of U.S. Forces decreases and high technology weapons are now readily available on the world market. In this new environment, it is imperative that U.S. forces possess technological superiority to prevail. The technological advantage we enjoyed in Desert Storm and still enjoy today is a legacy of decades of investment in Science and Technology (S&T). Likewise, our future warfighting capabilities will be substantially determined by today's investment in S&T.

In peace, technological superiority is a key element of deterrence. In crisis, it provides a wide spectrum of options to the National Command Authorities and Commanders in Chief, while providing confidence to our allies. In war, it enhances combat effectiveness, reduces casualties and minimizes equipment loss. In view of declining defense budgets and manpower reductions, advancing military technology is a national security obligation of ever greater importance.

To fulfill this obligation, the Director, Defense Research and Engineering has continually enhanced the strategic planning process for Defense Science and Technology (S&T). The foundation of this process is the *Defense S&T Strategy* that is supported by the *Basic Research Plan*, *Joint Warfighting S&T Plan*, and this *Defense Technology Area Plan*. These documents present the DoD S&T vision, strategy, plan, and objectives for the planners, programmers, and performers of Defense S&T. Revised annually, these documents are a collaborative product of the Office of the Secretary of Defense (OSD), Joint Staff, Military Services, and Defense Agencies. The *Strategy* and *Plans* are fully responsive to the White House National Security S&T Council *National Security S&T Strategy* and the Chairman of the Joint Chiefs of Staff's *Vision* and *Joint Vision 2010* as shown in Figure 1.1. The Strategy and Plans and supporting individual S&T Master Plans of the Military Services and Defense Agencies guide the annual preparation of the Defense Program and Budget. The Strategy and Plans are made available to the United States Government, defense contractors, and our allies with the goal of better focusing our collective efforts on superior joint warfare capabilities and improving interoperability between the United States and our allies.

The *Basic Research Plan* (BRP) presents the DoD objectives and investment strategy for DoD sponsored research performed by universities, industry, and Service laboratories. In addition to presenting the planned investment in 12 broad research areas,

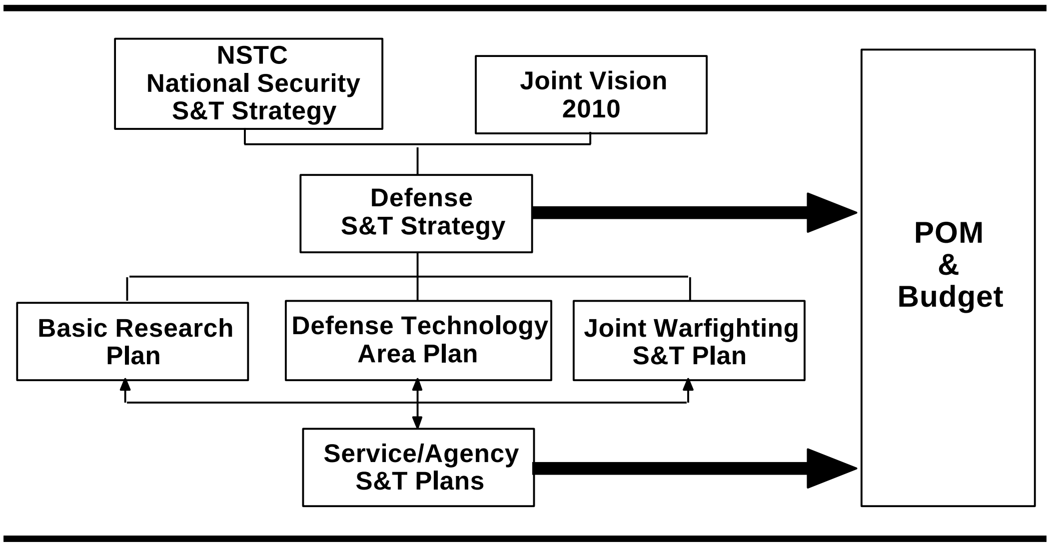

Figure 1.1. Science and Technology (S&T) Strategic Planning

this year's plan highlights 10 strategic research objectives holding great promise for the development of enabling breakthrough technologies for revolutionary 21st Century military capabilities.

The *Joint Warfighting S&T Plan* (JWSTP) takes a joint perspective horizontally across the Services and Defense Agencies to ensure that the requisite technology and advanced concepts for superior joint and coalition warfighting are supported. It ensures that the near-, mid-, and long-term needs of the joint warfighter are properly balanced and supported in the S&T planning, programming, budgeting and assessment activities of the DoD. The JWSTP is focused around 12 Joint Warfighting Capability Objectives. These objectives support the Joint Warfighting Capabilities Assessment and the four leveraged concepts emphasized in the Joint Vision 2010: dominant maneuver, precision engagement, full-dimension protection, and focused logistics. A significant feature of the JWSTP is the identification of mechanisms for the timely transition of technology to the warfighter in the field before it is obsolete or found in the hands of our adversaries.

This *Defense Technology Area Plan* (DTAP) presents the DoD objectives and investment strategy for technologies critical to DoD acquisition plans and the *Joint Warfighting S&T Plan*. The DTAP also takes a horizontal perspective across the Service and Defense Agency efforts, thereby charting the total DoD investment for a given technology. The DTAP documents the focus, content, and principal objectives of the overall DoD science and technology efforts. This plan provides a sound basis for acquisition decisions and is structured to respond to the DDR&E emphasis on rapid transition of technology to the operational forces.

Taken together these three documents provide programming guidance for the DoD S&T Community.

DTAP DEVELOPMENT PROCESS

The DTAP is one of the principal products of an integrated science and technology strategic planning process, supported by Defense Science and Technology Reliance. Development of the DTAP is the responsibility of the Defense Reliance Executive Committee (EXCOM) now chaired by the Deputy DDR&E. The EXCOM oversees the work of ten Defense Technology Area Panels, each responsible for a specific Technology Area. The Technology Area Panel membership consists of Service ad appropriate Defense agency technical specialists and is chaired by a senior Service S&T manager. These individuals have basically continued the integrated planning activities initiated under Tri-Service S&T Reliance. The ten Technology Area Panels, the Service chairs and DDT&E staff points of contact are shown in Figure 1.2. To ensure that the DTAP achieves its stated purpose, the Defense S&T Reliance network has developed the following goals to guide the effort.

- Enhance the quality of Defense S&T activities and develop world class products
- Ensure the existence of critical mass effort in key technologies.
- Gain productivity and efficiency through collocation and consolidation of in-house S&T work
- Preserve the vital mission-essential capabilities of the Services throughout the process

This DTAP identifies the anticipated return on the S&T investment through nearly 200 Defense Technology Objectives (DTOs) in ten broad technology areas. Each DTO identifies a specific technology advancement that will be developed and/or demonstrated, the anticipated date of technology availability, and the specific benefits resulting from the technology advance. These benefits not only include increased military operational capabilities, but also address other important areas including affordability and dual use applications, which have received special emphasis in the *Defense S&T Strategy*.

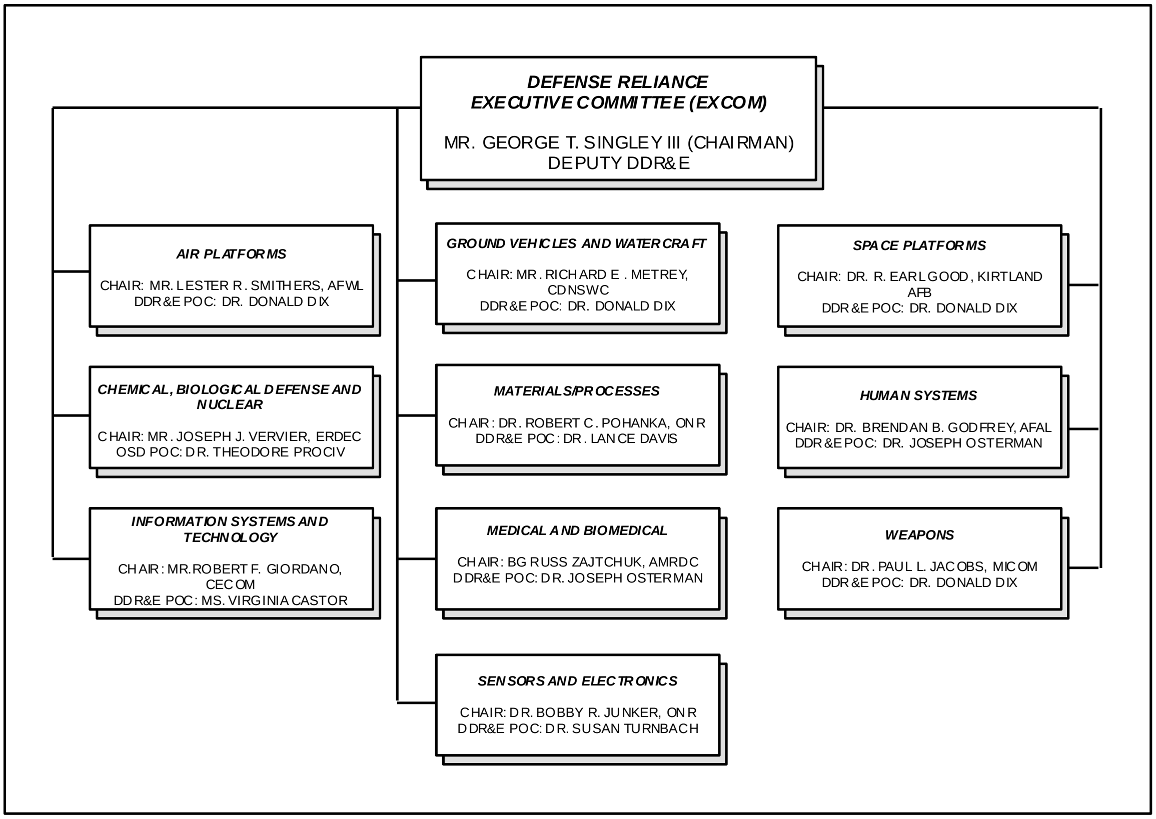

Figure 1.2. Defense Technology Area Plan Key Personnel

ENABLING AND SUPPORT TECHNOLOGIES

The Defense Technology Objectives (DTOs) provide focus for the development of technologies that address an identified military need. This DTAP also addresses the continued development of the enabling technologies which are critical to sustaining the DTOs, laying the foundation for future DTOs, and to prevent technological surprise. These technology development activities involve proof of concept experiments, laboratory demonstrations, and evaluations supported by models and simulations. The technology developments also provide for the investigation of innovative technologies that could have significant impact on military applications across a broad spectrum of applications.

More than half of the DTOs are supported by two or more Services and/or Defense Agencies. Allocation of Defense S&T resources must also consider Service unique requirements which are not addressed in detail in this DTAP. The execution of the S&T programs to attain the DTOs and objectives unique to the Services and Agencies is accomplished through the Service and Defense Agency plans, as shown in Figure 1.1.

RESOURCES

Figure 1.3 depicts the combined Exploratory Development (6.2) and Advanced Technology Development (6.3) Science and Technology funding associated with the DTAP. The portion of this DTAP funding related to DTOs is also depicted.

The DTAP identifies the advanced concepts and enabling technologies essential to enhancing high priority joint warfighting needs and which will receive funding precedence in the President's Budget and accompanying FYDP.

FY 1997
DEFENSE TECHNOLOGY AREA PLAN (DTAP)
$ in thousands

DTAP	Total Funding	DTO Funding
Air Platforms	393,268	361,000
CB Defense and Nuclear	188,953	121,600
Info Systems and Tech	1,533,831	763,200
Ground Vehicles and Watercraft	254,679	163,100
Materials and Processes	724,185	458,800
Biomedical	266,890	79,600
Sensors and Electronics	1,003,904	712,700
Space Platforms	131,348	94,300
Human Systems	255,194	106,600
Weapons	1,171,359	270,800
TOTAL	5,923,611	3,131,700

Figure 1.3. FY97 DTAP Funding

The following chapters describe the technology development plans for each of the ten technology areas. The strategic goals and acquisition and warfighting needs identified for the technical area are presented, along with a list of the applicable Defense Technology Objectives. These are followed by discussion of each sub-area wherein the specific warfighter needs, goals and timeframes, major technical challenges, related federal and private efforts, and the S&T investment strategy are identified. The chapters conclude with Technology Development Roadmaps for the attainment of the DTOs, and related funding information. The full text of each of the DTOs is given in the DTO Appendix to the DTAP and *The Joint Warfighting Science and Technology Plan*.

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I. FY 1997 DEFENSE TECHNOLOGY AREA PLAN FOR AIR PLATFORMS

1. INTRODUCTION

1.1 Definition/Scope

This technology area includes efforts devoted to basic air vehicles and cruise missiles. There are five major subareas (see Figure I.1.): (1) fixed wing air vehicles, focused on aerodynamics, structures, flight control, and vehicular subsystems; (2) rotary-wing vehicles, focused on aeromechanics, structures, flight control, and vehicular subsystems; (3) the Integrated High Performance Turbine Engine Technology (IHPTET) program, focused on gas-turbine propulsion; (4) aircraft power, focused on non-propulsive power generation; and (5) high-speed propulsion and fuels, focused on ramjet, scramjet, and combined-cycle engines for missiles (and other air vehicles) and fuels.

Air Platforms Technology interfaces with all technology areas impacting on aircraft and cruise missile systems: Information Systems and Technology, Materials/Processes, Sensors and Electronics, Human Systems, and Weapons. See Resource Appendix for funding of this Defense Technology Area.

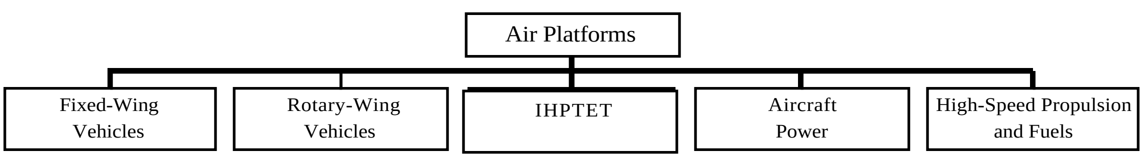


Figure I.1. Planning Structure - Air Platforms Technology Area

1.2 Strategic Goals

Figure I.2. illustrates some of the Air Platform Technology transition goals. The overarching strategic goal for air platform technology investment is to maintain world-wide military superiority in aircraft. More specifically, the goals include providing the technology by 2010 which enables options for: doubling the range of aircraft with no increase in weight; a factor of two reduction in gross weight for the same mission capability; a factor of two reduction in acquisition and support costs; doubling the life of DoD Air Vehicles; and greatly reduced signatures.

These goals can be achieved through the pursuit of specific technology goals in the major subareas of air platform technology by improving aerodynamics, reducing structural weight fraction, doubling propulsion system capability, increased efficiency and reduced weight of auxiliary power systems, reducing the production and support costs, and increasing the thermal capability of fuels.

		Years		
Sub-Area	**Current Baseline**	**5**	**10**	**15**
Fixed-Wing Vehicles	F-22,F/A-18/E/F, C-17, B-2	F-22, F/A-18E/F upgrades, JSF, C-17, B-2 upgrades	F-22,F/A-18E/F impts, JSF upgrades, C-17, B-2 impts	JSF impts, SOF, UAV, Med range Bomber
Rotary-Wing Vehicles	AH-64A OH-58D CH-47D CH-46E CH-53E UH-1N/AH-1W UH-60A	AH-64D OH-58D CH-47D V-22 CH-53E UH-1N/AH-1W UH-60A/L	AH-64D RAH-66 ICH V-22 CH-53 (mod) UH-1N/AH-1W UH-60A/L	RAH-66 (upgrade) RAH-66 (upgrade) JTR V-22 JTR CVLA UH-60 (upgrade)
IHPTET	YF119 (Turbofan/ Turbojet) J402/F107 (Expendable Turbine Engines) T700/T406 (Turboshaft/ Turboprop)	F-22, F/A-18E/F upgrades, JSF V/STOL Supersonic wpn Longer loiter UAV Low cost wpn V-22	C-17 impts, B-2 impts Long loiter UAV RAH-66	Global strike A/C, JSF impts, SOF, Med Rng bomber Ultra low cost standoff weapon, Very long range/long loiter UAV RAH-66 (upgrade)
Aircraft Power	Aircraft Power Components	C-130J E-8 JSTARS	C-5 upgrade C-130 upgrade JSF	Global strike A/C, JSF impts, SOF, Med Rng bomber
High Speed Propulsion and Fuels	Ramjet/Scramjet Propulsion SR-71 High Heatsink Fuels	Adv AMRAAM Cheap Mach 4 wpn Existing fleet	Combined Cycle Engine Combined Cycle Engine HyTech Weapon Fuel	Mach 8 missile Mach 5+ aircraft Hypersonic Aircraft Fuel

Figure I.2. Air Platform Technology Transition Opportunities

1.3 Acquisition/Warfighting Needs

Aircraft-related acquisition, operation and support costs constitute about 1/3 of the DoD budget, and about 2/3 of these costs are associated with the basic air platforms. The relative importance of aircraft in the force structure is not expected to change; there are no foreseeable substitutes for the combination of firepower and mobility provided by aircraft.

Air platforms are critical to providing a military operational capability for strike, military airlift, early warning, reconnaissance, command and control, ground attack and sea control. Air platforms are also critical to many operational tasks including air defense, air superiority, close air support, command control and communications, disaster assessment and relief, electronic warfare, information warfare, interdiction, medical evacuation, missile defense, reconnaissance and surveillance, sea lane control, search and rescue, special operations, strategic and theater airlift, strategic attack, strategic deterrence, and weather observation. To meet their operational objectives, the warfighters need new and enhanced capabilities based on the air platform technology developments. These capabilities include a 25% increase in mission range, a 25% increase in pay load, and a 30% increase in mission survivability.

Technologies have transition potential to a wide variety of military aerospace systems, i.e., F-15/F-16/F-18/AH-64 upgrades; RAH-66/V-22/F-22 growth; F-18/F-22 derivatives; and new strike fighter developments. Air platform technologies have strong dual-use application in the civil sector, thus strengthening U.S. international competitiveness and significantly enhance our economic security. Commercial applications of these technologies are in aerodynamics, gas turbines, power-by-wire controls, electrically-driven subsystems (e.g., brakes), extended-life tires, low-cost transparencies, and aging aircraft life extension, electric actuators, low-cost light-weight structures, and multi-disciplinary design optimization.

2. DEFENSE TECHNOLOGY OBJECTIVES (DTO)

2.1 Fixed-Wing Vehicles

- AP.01.03.NF Fighter/Attack Aircraft Technology
- AP.02.12.NF Airlift/Patrol/Bomber Aircraft Technology
- AP.03.09.NF Special Operations Forces Aircraft Technology

2.2 Rotary-Wing Vehicles

- AP.04.00.AN Helicopter Active Control Technology (HACT)
- AP.05.00.AN (not used)

2.3 Integrated High Performance Turbine Engine Technology (IHPTET)

- AP.06.00.NF Fighter/Attack/Strike Propulsion
- AP.07.00.ANF Transport/Patrol/Helicopter Propulsion
- AP.08.00.NF Cruise Missile/Unmanned Air Vehicle Propulsion

2.4 Aircraft Power

- AP.09.00.NF Aircraft Power (MEA)
- AP.10.00.AN Rotorcraft Drive

2.5 High Speed Propulsion And Fuels

- AP.11.00.NF High Speed Propulsion
- AP.12.00.F Hydrocarbon Scramjet Missile Propulsion (HyTech)
- AP.13.00.F High Temperature Fuels

3. TECHNOLOGY DESCRIPTIONS

3.1 Fixed-Wing Vehicles

3.1.1 Warfighter Needs

Fixed-Wing vehicles are the backbone in terms of global power and reach and operations from the sea for both our national defense and power projection abroad, supporting four of the five Joint Chiefs' of Staff (JCS) top future war fighting capabilities. Air vehicles are critical to providing air defense; air superiority; close air support; command, control and communications; disaster assessment and relief; electronic warfare; information warfare; interdiction; missile defense; reconnaissance and surveillance; sea lane control; search and rescue; special operations; strategic and theater airlift; strategic attack; strategic deterrence; and weather observation.

The Air Force Modernization and Planning Process and Navy S&T Requirements Guidance differ in detail but share the common overall objective to improve warfighter capability. Upgrades, improvements to current systems (Today's Aircraft Flying Tomorrow) and providing for the future of military aviation (Future Aircraft Technology Enhancement) is the responsibility of the Fixed Wing Vehicles (FWV) Subarea. S&T planning for such upgrades, improvements and vision for future system possibilities is captured and reported in the FWV Technology Development Approach (FWV TDA). This document lays out the DoD strategy for setting and achieving the goals which will result in the highest payoffs (Figure I.3.) for the aviation community. Implementing the strategy will result in significant improvements in range, payload and mission survivability.

Fixed Wing Technologies focus on providing aircraft that meet the DoD operational capability and affordability requirements, both now and for the future. All DoD S&T in this subarea is accomplished by the Air Force and Navy (including the Marine Corps).

⇓Air Vehicles Payoffs ⇓ Timelines ⇒	2000	2005	2010
Fighter/Attack [Baseline] ⇒	[F-22, F-18 E/F]	[F-22, F-18 E/F]	[F-22, F-18 E/F]
		Percent (%) Improvement	
Reduced Acquisition Costs	10	20	30
Reduced Operations and Support Costs	10	15	30
Increased Lethality	5	10	15
Increased Mission Range	25	30	35
Reduced Susceptibility	15	20	30
Increased Payload	25	30	35
Increased Operational Readiness	10	15	20
Reduced Vulnerability	15	20	25
Reduced Takeoff Gross Weight	10	15	20
Airlift/Patrol/Bomber [Baseline] ⇒	[C-17, P-3, B-2]	[C-17, P-3, B-2]	[C-17, P-3, B-2]
Reduced Acquisition Costs	10	15	20
Increased Survivability	10	20	30
Reduced Operations and Support Costs	10	15	20
Increased Mission Range	20	30	40
Increased Mission Endurance	15	25	30
Increased Operational Readiness	10	15	20
Increased Bomber Lethality	5	10	15
Increased Payload	20	25	30
SOF [Baseline] ⇒		[AC/MC-130]	
Increased Mission Survivability	30	40	50
Improved Clandestine Operations	40	60	75
Increased Austere Operations Capability	5	10	15
Increased Operational Readiness	10	15	20
Increased Mission Range	15	30	40
Reduced Field Length	20	30	50
Reduced Acquisition Costs	10	15	20
Reduced Operations and Support Costs	10	15	20

Figure I.3. Fixed Wing Vehicle Payoffs

3.1.2 Fixed Wing Vehicles Overview

3.1.2.1 Goals and Timeframes. Aggressive goals (Figure I.4.) have been established to both increase the combat effectiveness of DoD fixed wing aircraft and maintain the nation's preeminence in the aircraft industry. Six Technology Efforts (Aerodynamics, Flight Control, Structures, Vehicle Subsystems, Integration and Maritime

Unique Technology) are clearly focused on overcoming the barriers with the highest potential for improving overall system affordability and performance.

Fixed Wing Vehicles ⇒	Fighter Attack			Airlift/Patrol/ Bomber			SOF		
Timelines ⇒	2000	2005	2010	2000	2005	2010	2000	2005	2010
Goals ⇓	**Percent (%) Improvement over SOA Baseline (TBD = to be determined)**								
Reduced Production Costs at T1	20	30	40	20	30	40	20	30	40
Reduced Support Costs	20	30	40	20	35	45	20	30	40
Reduced Signature (IR)	35	45	55	20	30	40	20	40	60
Reduced Signature (RF) (% dB)	25	40	60	25	40	60	100	125	150
Reduced Visual Signature	*	*	*	*	*	*	20	35	50
Reduced Acoustic Signature	*	*	*	*	*	*	60	75	80
Reduced FWV Weight Fraction	20	25	35	20	25	30	20	25	30
Increased Max Trimmed C_L @ Takeoff/Landing	*	*	*	*	*	*	33	133	233
Increased Lift/Drag	10	25	30	10	25	30	10	20	30
Reduced Development Time	20	35	45	20	35	45	20	30	40
Increased Reliability	30	50	65	65	50	65	30	40	50
Reduced Support Volume	10	15	25	10	15	25	10	15	25
Increased Safety of Launch/Recovery Ops	10	15	25	*	*	*	10	15	25
Increased Agility - Longitudinal	10	20	40	*	*	*	*	*	*
Increased Agility - Lateral Directional	10	20	40	*	*	*	*	*	*
Reduced Vulnerable Area	tbd	tbd	tbd	*	*	*	*	*	*
Increased Payload Flexibility	*	*	*	10	20	30	*	*	*

* Not Applicable or Not Available

Figure I.4. Fixed Wing Vehicle Technology Development Goals

3.1.2.2 Major Technical Challenges. The major technology challenges are control of boundary layer transition for variable camber wings, providing control of flow separation in Low Observable (LO) configurations, retaining performance in lightweight short inlets, uncertain flight control design models, adequate actuator power and response independent of central hydraulic system, reducing weight of major load-carrying structure while reducing cost and ballistic vulnerability, design concepts to reduce the costs of composite structures, demonstrating injection molded frameless transparencies, applying titanium matrix composites to demonstrate affordable, light weight landing gear, demonstrate a more electric aircraft subsystem, creating an effective process for seabased

servicing, and on-the job training, develop and demonstrate an active aeroelastic wing, and flight demonstrate innovative tailless aerodynamic control and airframe-mounted, LO thrust vectoring technology, repair techniques for aging aircraft, and the development of methods to reduce the design time of air vehicles.

3.1.2.3 Related Federal and Private Sector Efforts. FAA Aging Aircraft and Commercial Aircraft Hardening Programs, SBIR, IRAD, Great Lakes Composite Consortium (GLCC).

Cooperative programs with Canada in Nonlinear Aerodynamics, Cargo Handling and Landing Gear Development. Improved Cargo Handling program with Germany and France.

Cooperative programs through The Technical Cooperation Program (TTCP) with Canada, UK, and Australia in the areas of aerodynamics, flight dynamics, and aircraft/ship interface.

NASA High-Speed Research (HSR) and Advanced Subsonic Technology (AST) programs. NASA participates as integrated planning partners in numerous joint and cooperative programs, while conducting coordinated research in commuter, subsonic transport, and high-speed/hypersonic vehicles (and their propulsion systems) which have application to military aircraft, ARPA Pilots Associate program and four technology reinvestment projects, Halon Replacement - DoD and international.

3.1.3 S&T Investment Strategy

The Air Force and Navy laboratories develop multi-disciplinary tools, methods, components, and component-level (or “Technology Effort Level”) subsystems, and integrate these components to demonstrate system-level payoff potential. This process avoids the risk of sub-optimizing component-level efforts and provides the prioritization criteria for investment strategy.

3.1.3.1 Technology Demonstrations

3.1.3.1.1 Extended Range Demo (ERD) Technology Demonstration (TD)—fulfill DTO AP.01.03.NF Fighter/Attack Aircraft Technology. The ERD TD conducts a full envelope (takeoff, low level penetration, up-and-away maneuvering, supersonic dash, and landing) military flight evaluation of a reduced vertical tail/no rudder fighter aircraft utilizing an optimum blend of control effectors as a substitute for vertical tail/rudder aerodynamic control. This test will demonstrate the substantial drag reduction/range improvement of a reduced vertical tail/no rudder configuration that retains fighter maneuverability without compromising flight safety.

This program will build directly on the joint USAF/NASA and contractor $30M investment on the F-15 ACTIVE testbed vehicle. Working within an existing NASA Dryden task contract, the USAF initiated a FY95 new start task to develop integrated control logic and to substantially modify the vertical tails (remove rudder and approximately one-half vertical surface) on the F-15 ACTIVE vehicle. Based on a signed MOA, NASA Dryden will lead the flight evaluation with participation by AFFTC. The flight evaluation will include a logical progression of more aggressive experiments including fixed rudder, use of the rudder to artificially produce reduced yaw stability, and finally a rudderless, half-size vertical tail. Testing will assess drag reduction and maneuvering capabilities

across the entire F-15 operating envelope and will build confidence in the use of propulsion control as major design consideration for future tailless fighter aircraft.

3.1.3.1.2 VISTA Simulation System Upgrade Technology Demonstration (TD)—fulfill DTO AP.01.03.NF Fighter/Attack Aircraft Technology. This TD will augment the current F-16 VISTA in-flight simulator with an integrated control system with pitch/yaw thrust vectoring to provide a permanent, militarized facility for high-angle-of-attack in-flight simulation, weapons research, and flight research. By enhancing the simulation capability of the VISTA/NF-16D, VISTA would be used not only for continued research and development into high-angle-of-attack flight, but also serve as a testbed allowing for significant risk reduction demonstrations of technologies for current and future systems.

This effort will build on the integrated controls with thrust vectoring tech base provided by the Multi-Axis Thrust Vectoring (MATV) program. Contracts were awarded to Calspan (the VISTA operations contractor), Lockheed Ft Worth Company, and Pratt & Whitney in early FY95 to design, fabricate, and modify the VISTA/NF-16D with a production-like, full flight envelope axisymmetric thrust vectoring nozzle. VISTA enhancements will also include the incorporation of a programmable display system (including two helmet-mounted displays) and high bandwidth actuators for increased simulation fidelity. Once this configuration is validated in ground test, a rigorous, full-envelope flight test program will begin. This flight test program will demonstrate high fidelity in-flight simulation over the full flight envelope.

3.1.3.1.3 Active Aeroelastic Wing (AAW) Technology Demonstration (TD)—fulfill all three Fixed Wing Vehicles DTOs. The objective of this effort is to flight demonstrate key aspects of the highly innovative Active Aeroelastic Wing (AAW) concept. The AAW concept, which has been developed through exploratory analytical and wind tunnel tests, has a goal of improving maneuverability while reducing aircraft weight. Studies have shown this technology to provide a 7% to 20% reduction in aircraft takeoff gross weight.

An Active Aeroelastic Wing may be described as an aeroelastically tailored composite wing designed to require only the stiffness necessary for strength, buckling, and flutter. The wing is designed to respond aeroelastically to multiple leading and trailing edge control surface deflections and to exploit aeroelastically reversed controls, thus providing never-before-achieved wing flight control responses. An active control system is designed to maximize the utility of this control power, thus providing a high performance wing with complete control authority and power across the flight envelope. To reduce cost, an available fighter-type aircraft with a digital flight control system will be selected. Design studies will be performed to identify changes to the fighter's wing which increase the wing's flexibility and make the wing suitable for an AAW experimental demonstration. A high-rate actuation system will be installed to upgrade the fighter's leading edge control surface. Concurrent flight control development of AAW flight control strategies will also be conducted. Following modification of the fighter, a full envelope flight test will demonstrate some of the performance benefits which may be achieved through implementation of the AAW concept.

3.1.3.2 Technology Development

3.1.3.2.1 Aerodynamics. Aerodynamics technology will significantly improve aircraft performance by improving range, maneuverability, payload, affordability, and maintainability, while retaining low signature. Efforts are focused on refining analytical prediction methods and testing capabilities, and on improving the versatility and efficiency of modeling advanced aero vehicles. Technologists will use the computing power that has been developed over the last few years to explore and more fully understand those flight regimes that are characterized by highly dynamic, nonlinear aerodynamic flow (e.g., very high angle-of-attack maneuverability).

3.1.3.2.2 Flight Control. Flight Control technology provides air vehicle maneuverability, stability, and flight path control (including multi-ship control), while assuring safety of flight. It contributes to increased range, reduced susceptibility, and increased lethality by focusing substantial flight control technology development effort on vertical tailless supersonic fighter aircraft concepts. Austere operations are supported by flight control efforts in low-visibility weather autonomous landing guidance systems. Reduced acquisition costs are supported through efforts in low cost modeling and low cost control system design techniques. Reduced operations and support costs are addressed by technology developments in electric actuation, optical air data systems, and photonic vehicle management systems.

3.1.3.2.3 Structures. Airframe Structures covers the development of improved structures for all classes of fixed-wing aircraft, from analysis through concept development, experimental applications, and incorporation into the operational fleets. The scope covers aging aircraft, smart structures, affordable composite and advanced metallic structures, extreme environment structures, new construction methods, multi-disciplinary design optimization, and new manufacturing techniques. These technologies will enable us to provide structures that are cheaper, lighter, more durable, and require less maintenance.

3.1.3.2.4 Subsystems. Vehicle Subsystems focuses on a balance of technology developments in aircraft subsystems to decrease aircraft weight, increase mission range, reduce cost of ownership, and enhance survivability and safety, thus increasing warfighting capability.

3.1.3.2.5 Seabased Support. Seabased Support technology addresses technologies which improve the systems, equipment, and processes, on board aircraft or ships, that affect the launch, recovery, and operation of aircraft on and around sea-based platforms (e.g., aircraft carriers, air capable ships). The technology needs are in the areas of sea-based aviation launch, recovery, and terminal guidance operations aircraft, weapons and ship compatibility; and sea-based aircraft servicing, maintenance, support and handling. Technology advances in these areas will provide sea-based aircraft with enhanced availability, safety, supportability, and readiness in concert with increased affordability.

3.1.3.2.6 Integration. Integration Technology efforts are divided into two broad categories: Subsystem Level Integration Technology and System Level Integration Technology. Subsystem Level Integration Technology examines and exploits the interrelationships among two or more Air Vehicle technologies exclusively: vehicle aerodynamics, flight control, airframe structures, vehicle subsystems and carrier (maritime) unique. These efforts also include the integration of off-the-shelf, *non-developmental (i.e., current state-of-the-art technologies)* from non-Air Vehicles TAP areas such as Propulsion

and Power, Weapons, Avionics and Human Systems. Systems Level Integration Technology broadens the integration task to incorporate *developing* technologies from non-Air Vehicles technology areas as they are integrated with the air vehicle technology development.

Integration technology involves research and development, within DoD Air Vehicle R&D agencies, to integrate and demonstrate affordable technologies for fixed wing air vehicles. It is the process for planning, programming, and executing programs supporting technology selection. It involves development, and ground/flight test and evaluation, of advanced concepts integrating air vehicle aerodynamics, flight control, structures and aircraft subsystems, and Seabased Support technologies with other “non-Air Vehicles” technologies for current and future vehicles.

3.1.3.3 Basic Research. Basic research in robust multi-variable flight control supports acquisition cost and increased combat survivability. Work in real-time parameter identification and on-line control law design directly supports increased combat survivability. Research in computational fluid dynamics and computational electromagnetics supports improvements in combat range and survivability. Research in ballistic impact of composites will reduce combat vulnerability.

3.2 Rotary Wing Vehicles

3.2.1 Warfighter Needs

Operational capability improvements to both military and civil fleets will tremendously impact both the overall "cost of ownership" and the acceptance of rotorcraft by passengers and community. Reducing acquisition/operating costs, diminishing vibration and noise levels, and improving the night and adverse weather operations, all highlight the vast potential of rotary-wing technology advancements. These improvements goals were developed in concert with both the user and the rotorcraft industry through the development of the Rotary Wing Vehicle Technology Development Approach (TDA). This document lays out the DoD strategy for setting and achieving the goals which will result in the highest payoffs for the aviation community.

Operational capability requirements (OCR), as defined by the combat development user community, serve to identify the areas of rotorcraft performance and cost drivers which will most benefit from technological advancements. They also provide rationalization for the pursuit of technologies that provide solutions to real-world problems, avoiding work done "at the margin" which does not provide leap-ahead improvements to the effectiveness and affordability of both military and civilian rotorcraft. The specific RWV payoffs that have been established for three (3) classes of rotorcraft -- cargo, utility, and attack/reconnaissance (see Figure I.5.). These operational capability improvements are derived from the subsystem-level technology goals and their relationship to the subsystem-level technology goals are discussed in the DoD Rotary Wing Vehicle TDA.

	Cargo		Utility		Attack/Recon	
	2000	2005	2000	2005	2000	2005
Increase range at fixed payload, GW	72%	142%	55%	102%	76%	136%
Increase payload at fixed range, GW	60%	103%	36%	62%	57%	98%
Increase cruise speed	8%	15%	8%	15%	8%	15%
Increase maneuverability/agility	30%	50%	30%	50%	30%	50%
Decrease accident rate	30%	50%	30%	50%	30%	50%
Increase reliability	20%	45%	20%	45%	20%	45%
Improve maintainability	10%	20%	10%	20%	10%	20%
Increase probability of survivability	20%	40%	40%	60%	40%	60%
Reduce RDT&E costs	6%	9%	6%	9%	4%	6%
Reduce procurement costs	15%	30%	15%	30%	10%	20%
Reduce operation and support costs	5%	10%	5%	10%	5%	10%

Figure I.5. Rotary Wing Vehicle Payoffs

3.2.2 Rotary Wing Vehicles Overview

3.2.2.1 Goals and Timeframes. Aggressive goals have been established to both increase the combat effectiveness of DoD rotorcraft and maintain the nation's preeminence in the rotorcraft industry (see Figure I.6.).

	2000	2005
Reduce structural/hover-out-of-ground-effect weight ratio	13%	21%
Increase rotorcraft maximum Lift/Drag (L/D) ratio	8%	15%
Reduce Radar cross section (RCS)	25%	40%
Reduce Infrared (IR) signature	35%	50%
Reduce visual/electro-optical signature	35%	55%
Reduce acoustic radiation signature	4dB	7dB
Reduce vibration	40%	60%
Reduce development time	20%	35%
Reduce procurement cost per pound of structural weight	25%	40%
Reduce maintenance cost per flight hour per installed shaft horsepower	25%	50%
Improve handling qualities	CHPR 4	CHPR 3
Reduce number of flight safety components	30%	60%
Increase hardening to threats	20%	35%

Figure I.6. Rotary Wing Vehicle Technology Development Goals

3.2.2.2 Major Technical Challenges. The major technology challenges are the accurate prediction and control of stall**,** drag, and compressibility characteristics which will lead to overall rotorcraft performance improvements; determination of optimal rotorcraft response types, control laws and control law synthesis methods to achieve better handling qualities and shorten the design and development process; non-intrusive monitoring components and techniques, sensors, algorithms and methods to improve design and manufacturing processes and to permit real-time monitoring of flight loads and damage; actuators constructed using smart materials for primary control and vibration control of rotorcraft rotor blades, and understanding and modeling the effects of terminal area airwakes (e.g., ship superstructures) on the dynamics and flight control of rotorcraft..

3.2.2.3 Related Federal and Private Sector Efforts. Independent R&D (IR&D) efforts are conducted by the nation's four helicopter manufacturers. These efforts have been coordinated with the Technology efforts described above and some topics are being worked jointly through CRDA. Similarly NASA has a related rotary-wing technology development program and through the Army/NASA joint agreement provides essential people and facility resources which supplement and in many cases enable the Army Laboratory in-house efforts directed at the described goals.

3.2.3 S&T Investment Strategy

3.2.3.1 Technology Demonstrations

3.2.3.1.1 Helicopter Active Control Technology (HACT) Technology Demonstration (TD)—fulfill DTO AP.04.00.AN. The HACT TD brings together advanced concepts and components to demonstrate the potential improvements from second generation Active Control Technology. Specifically, HACT will exploit and develop refined concepts for control law design, distributed architecture, software development, and failure management coupled with advanced components for

fly-by-light and smart actuators. These have high potential to provide increased safety/reliability with shortened development times. In addition, the pilot will be provided with active cockpit flight controls and advanced displays. The total capability will be used to provide task tailored handling qualities to demonstrate improved mission effectiveness in critical tasks in all weather and night operations. These technologies would be applied as ingredients in current system upgrades or as a package in a new system such as JTR.

Current vertical lift aircraft pilot and flight management workload inhibits pilot situational awareness and response. These limitations directly impact night, adverse weather, and low altitude operations. Lack of complete control integration (fire/flight/fuel) prevents exploitation of full air vehicle capabilities, restricts maneuverability/agility, and impacts safety and survivability. Simplified implementation of digital flight control permits customer system-specific tailoring, fleet retrofit/system upgrade, reduces development and modification cost, and will be available for use in future military systems and in the civil arena.

3.2.3.2 Technology Development

Four technology efforts (Aeromechanics, Flight Control, Structures and Subsystems) are clearly focused on overcoming the barriers with the highest potential for improving overall system affordability and performance.

3.2.3.2.1 Aeromechanics. Aeromechanics science and technology seeks to improve the performance of rotorcraft while reducing the noise, vibrations, and loads inherent to helicopter operation. Efforts are focused on refining analytical prediction methods and testing capabilities, on improving the versatility and efficiency of modeling advanced rotorcraft, and on achieving breakthroughs through concept applications.

3.2.3.2.2 Flight control. Flight control technology defines the aircraft flying qualities and pilot interface to achieve desired handling qualities in critical mission tasks, synthesizes control laws that will facilitate a particular configuration achieving a desired set of flying qualities, and integrates advanced pilotage systems to the aircraft. The revolution in the power and miniaturization of computers holds tremendous promise in this field, permitting the realization of the full potential of the rotorcraft's performance envelope and maintenance of mission performance in poor weather and at night.

3.2.3.2.3 Structures. Structures science and technology focuses on the durability, safety, survivability, and affordability of critical rotary-wing vehicle components. Structures technology efforts are providing validated design and analysis tools, reliable life extension methods, and low-cost manufacturing processes to meet or exceed future RWV operational requirements. Improvements in structures technology enhance structural efficiency and performance while reducing both acquisition and operating costs of existing and future rotary-wing vehicles. Without low-cost manufacturing, composites technology cannot reach a level of maturity to compete with metals in providing strength, stiffness, and durability benefits. "Virtual prototyping" will be incorporated to optimize structural designs and to minimize risk in exploring new concepts for future RWV development programs.

3.2.3.2.4 Subsystems. Rotary-wing Vehicle subsystems encompass a broad range of science and technology topics related to the support, sustainment, and survivability of increasingly complex aircraft systems, and to the unique problems

associated with the application of high performance weapons on rotorcraft. In addition to addressing affordability issues for operation and support (O&S) costs, this area also encompasses the extension of the useful life of weapon systems through upgrading the armament and other mission equipment. Vehicle subsystems also address the TDA objectives of hardening to threats through electro-optical signature reduction, improved crashworthiness, and ballistic tolerance of rotorcraft.

3.2.3.3 Basic Research. The RWV Basic Research program is focused entirely upon Aeromechanics and Structures technology. The Aeromechanics efforts are directed toward rotor performance and acoustics, computational fluid dynamics, aeroelastic stability, and structural dynamics; deliverables include improved understanding of physical phenomena, mathematical models and complex computer codes which are disseminated to Government, academia, and industry. The Structures basic research program develops advanced structural analyses, failure criteria, and inspection methods which address fundamental technology deficiencies in both metallic and composite rotorcraft; the overall thrust is to provide an integrated stress-strength-inspection technology for life extension of existing and durability of future rotary-wing vehicles.

3.3 Integrated High Performance Turbine Engine Technology (IHPTET)

3.3.1 Warfighter Needs

The propulsion system (engines plus fuel) typically accounts for 40% to 60% of the takeoff gross weight for previous, current, and developmental aircraft, and about 20% of the aircraft acquisition and operation costs. Accordingly, the increase in engine performance and reduction in engine costs associated with the IHPTET goals will be a major contributor to achieving the air platform capabilities cited in Section 1.3; illustrative examples include a 115% increase in radius for an upgraded F-18; a 35% reduction in gross weight and acquisition cost for a new fighter; and an F-18 size STOVL aircraft with greater range/payload capability than the F-18. In the nearer term, technology developed by IHPTET is currently being transitioned to the F414 engine for the F-18E/F, the F119 engine for the F-22, the T800 for the RAH-66, and the J407 for the ITALD and several civil engines. Future military transition opportunities include engine upgrades for the F-15, F-16, AH-63, H-60, H-37 and Tomahawk, and new systems such as JAST/ASTOVL, ACT, Common Light Vertical System Replacement, and Supersonic Standoff Weapon. IHPTET will also provide the propulsion technologies for the National Transport Rotorcraft program. IHPTET also provides the basis for continued preeminence in civil aircraft engines, as the technology is largely dual use in nature; in this context, IHPTET is the primary building block for the NASA Advanced Subsonic Technology and High-Speed Research programs directed specifically at civil engines.

3.3.2 IHPTET Overview

3.3.2.1 Goals and Timeframes. The IHPTET program was initiated in 1988 to achieve the goals shown below. They are referenced to the 1987 state-of-the-art for three classes of engines: turbofan/turbojet (TF/TJ), turboshaft/turboprop (TS/TP), and expendable (EXP). All goals are based on maintaining current levels of durability and life. These goals

and others that follow (see Figure I.7.) include current and planned Defense Technology Objectives as shown on the roadmap.

1991	TF/TJ: TS/TP: EXP:	+30% thrust/weight; +100 F combustor inlet temperature; (- 20% fuel burned); +40% power/weight; -20% specific fuel consumption; +35% thrust/airflow; -20% specific fuel consumption; -30% cost.
1997	TF/TJ: TS/TP: EXP:	+60% thrust/weight; +200 F combustor inlet temperature; (-30% fuel burned); -20% acquisition cost; -20% maintenance cost; +80% power/weight; -30% specific fuel consumption +70% thrust/airflow; -30% specific fuel consumption; -45% cost.
2003	TF/TJ: TS/TP: EXP:	+100% thrust/weight; +400 F combustor inlet temperature; (-40% fuel burned); -35% acquisition cost; -35% maintenance cost +120% power/weight; -40% specific fuel consumption; +100% thrust/airflow; -40% specific fuel consumption; -60% cost.

Figure I.7. IHPTET Technology Development Goals

3.3.2.2 Major Technical Challenges. The general path to doubling propulsion system capability is well known. Higher temperatures at combustion initiation are required to increase efficiency (or decrease specific fuel consumption) and expand the flight envelope; higher maximum temperatures are required to increase the output per unit airflow; less weight per unit airflow is required to increase the output per unit weight (thrust/weight or power/weight ratio); and all of the preceding advances must be accomplished while maintaining or increasing internal component efficiency, durability, and life, and decreasing cost. Specific technology development areas include: increased aerothermodynamic design capability for improved component efficiency levels and control of heat transfer; higher temperature and lower density materials; innovative structural concepts; and compatibility of these developments with affordable manufacturing processes.

3.3.2.3 Related Federal and Private Sector Efforts. Both NASA and industry participate in IHPTET. NASA investment is approximately $20 million in FY95. Industry's discretionary funding focused on IHPTET efforts is estimated to be

approximately $100 Million in FY95. NASA also has two efforts directed specifically at civil engine technology that build upon IHPTET. These efforts are the High Speed Civil Transport (HSCT) program and the Advanced Subsonic Transport (AST) program.

3.3.3 S&T Investment Strategy

In executing IHPTET, focus is maintained on specific technology demonstrations, in order that the technology effort at the component level can also be focused. National investments among the various technology demonstration and technology development efforts are allocated in accordance with their potential payoff to warfighting needs and their relative contribution to achieving the IHPTET goals.

3.3.3.1 Technology Demonstrations. Technology Demonstrations for IHPTET are divided into the three fundamental classes of gas turbine engines: (1) man-rated thrust engines (turbofan/turbojet), (2) man-rated shaft power engines (turboshaft/ turboprop), and (3) expendable missile and/or unmanned air vehicle engines. Each class is treated as a separate family of demonstrations. In all cases, the technology demonstrators have two broad objectives. The first is evaluating integrated component behavior in a realistic environment; indeed, in the case of the turbine component specifically, these demonstrators offer the first realistic opportunity to evaluate component technology development efforts. These evaluations are used to guide the further development of component technology. The second broad objective is to validate that the technology is sufficiently developed and understood to be transferred to new engine developments and to upgrades of existing engines.

3.3.3.1.1 Turbojet/Turbofan Engine Class Technology Demonstration—fulfill DTO AP.06.00.NF Fighter/Attack/Strike Propulsion. They are conducted in building block fashion, with successive introduction of advanced component technology, and the initial demonstration is in a gas-generator configuration within the Advanced Turbine Engine Gas Generator (ATEGG) effort. The final demonstration is in a full engine configuration within the Joint Technology Demonstrator Engine (JTDE) effort.

3.3.3.1.2 Turboshaft/Turboprop Engine Class Technology Demonstration—fulfill DTO AP.07.00.ANF Transport/Patrol/Helicopter Propulsion. They are also conducted in building block fashion, and the demonstration is in a gas-generator configuration only within the Joint Turbine Advanced Gas Generator (JTAGG) effort.

3.3.3.1.3 Expendable Engine Class Technology Demonstration—fulfill DTO AP.08.00.NF Cruise Missile/Unmanned Air Vehicle Propulsion. They are also conducted in building block fashion, and the demonstrations are in a full engine configuration within the Joint Expendable Turbine Engine Concepts (JETEC) effort.

3.3.3.2 Technology Development. Technology advances in all of the constituent areas of a gas-turbine engine are required to achieve the IHPTET goals. These constituent areas are the basis for individual technical efforts that are aimed at specific, time-phased objectives that, if achieved, will collectively result in achievement of the IHPTET goals, and are identified below:

3.3.3.2.1 Compression Systems. Compression systems consist of fans, compressors, and internal (secondary) flow systems. The major advances required in compression systems are increases in polytropic efficiency, increases in specific output of a

compression stage (measured by stage loading), reductions in weight, reductions in leakage flows, and the ability to operate at higher compressor exit temperatures.

3.3.3.2.2 Combustion Systems. Combustion systems are divided into two areas, combustors and augmentors. For combustors, the major advances required are increases in both inlet and outlet temperature capability, reductions in weight, decreased exit temperature variations (measured by pattern factor), increases in the ratio of maximum/minimum fuel flow rate (the turndown ratio), and decreases in specific volume (measured by the heat release rate - combustion energy release rate per unit volume). For augmentors, the major advances required are increases in temperature capability, reductions in weight (by reducing system length), reduction in pressure loss (measured by the dry pressure loss - pressure loss in the absence of heat release), and efficiency.

3.3.3.2.3 Turbine Systems. Turbine systems include turbine vanes, blades, shrouds, disks, cases, support frames and internal cavity flow hardware. The major advances are increases in temperature capability, reductions in cooling flow requirements, increases in work done per stage (measured by stage work - work produced per unit mass flow), and increases in thermodynamic efficiency.

3.3.3.2.4 Exhaust Systems. Exhaust systems include exhaust nozzles, associated structure, and signature reduction features. The major advances required are decreases in weight for both treated and untreated nozzles, reduction in augmentor cooling flow requirements, reductions in leakage, and improved functionality in thrust vectoring.

3.3.3.2.5 Controls and Accessories. Controls and accessories include the engine fuel management systems and engine/nozzle variable geometry controls, and associated pumps, valves, piping, sensors, actuators, cabling, and digital control computers. Achievement of sub-area goals requires major advances in control system functionality (thrust vectoring, stall/surge control), and significant reductions in component and control subsystem weight.

3.3.3.2.6 Mechanical Systems. The primary components of mechanical systems are bearings, seals, shafts, gearing, and lubrication systems. The major advances required are increases in the temperature capability of lubricants, increases in the speed capability of bearings and air/oil seals, efficient methods of rotor thrust control, and reductions in weight.

3.3.3.3 Basic Research. IHPTET places a high priority on the quality, content, support, and successful conduct of basic research. The products of the basic research represent significant independent contributions to the national technology base, and are normally intended to achieve new knowledge and understanding, to develop and maintain technical expertise/capability, and to provide new options and approaches for future efforts. Current focus is in the areas of turbine aero research, turbomachinery fluid mechanics, and combustion research to support gas turbine engine development.

3.4. Aircraft Power

3.4.1 Warfighter Needs

Operation payoffs for electrically-driven aircraft functions include 60-129 additional aircraft sorties in a 30-day war, 11-15% reduction in maintenance personnel needs,

10-12% aircraft vulnerability reduction, 7-20% reduction in C-141 deployment loads, up to 5% reduction in the frontal area of a new aircraft design, and reduction to a two-level maintenance of flight actuation subsystems (no hydraulic maintenance). Further cost savings are possible through the inherent higher reliability of the electrical systems over current systems. Environmental payoffs include the elimination of aircraft hydrazine usage, a significant reduction in hydraulic fluid and associated cleaning solutions usage (and thereby the need for disposal), and reduction in battery disposal due to an increase in useful life. Rotorcraft drive system payoffs include a 15% range increase or a 25% payload increase for an AH-64 anti-armor mission, a 50% reduction in drive system maintenance man hours per flight hour and a significant improvement in system-related readiness issues. The drive system source noise reduction translates directly into increased crew/pilot endurance in the short term and reduced hearing loss in the long term.

3.4.2 Aircraft Power Overview

3.4.2.1 Goals and Timeframes. The DoD aircraft power program represents a focused development of electrical power technology to significantly reduce costs and improve mission capabilities for DoD aircraft. This is being accomplished by developing new, electrically based, system level approaches and new technologies that are more reliable, lower mass, and lower cost than existing systems. Specific component improvements are in development to achieve the goals listed in Figure I.8.

1996	Weapon Power	0.1 kg/kW, 1 MW synchronous hyperconducting generator at 20K ; 20 kJ/kg, 10 kJ storage at 20K
1998	Aircraft Power	Eliminate need for central hydraulic system, through electric distribution and actuation; 2.5X increase in reliability; -50% in engine bleed air requirements
2000	Aircraft Power	3X reliability for auxiliary power units, 6600 kW/m^3 (250 Hp/ft^3) Integrated Power Unit, 0.5 kg/kV-A (1 lb/kV-A) starter/generator, life of aircraft 28 V batteries, hybrid electric/pneumatic/hydraulic actuation system, system fail/operate with 2 faults
	Rotorcraft Drive	Power-to-weight 25% increase, reduce noise by 10 dB, extend life to 12000 hrs
	Weapon Power	0.05 kg/kW, 1 MW synchronous high temperature superconducting generator at 40K ; 50 kJ/kg, 200 kJ storage at 70K
2005	Aircraft Power	7900 kW/m^3 (300 Hp/ft^3) Integrated Power Unit, environmentally safe 28 V batteries, 10 year 270 V batteries, no airframe mounted gearbox, 4X electrical system reliability, 2x reliability for electric flight control and brake actuation systems
	Weapon Power	0.03 kg/kW, 1 MW synchronous high temperature superconducting generator at 80K; 100 kJ/kg, 2 MJ storage at 80K
2010	Aircraft Power	Life of Aircraft 270 V batteries, 10,500 kW/m^3 (400 Hp/ft^3) Integrated Power Unit, 0.3 kg/kV-A (0.7 lb/kV-A) starter/generator, 10x reliability starter and generator, all electric actuation, 10X electrical system reliability
	Rotorcraft Drive	Power-to-weight 40% increase, no decrease in source noise or life

Figure I.8. Aircraft Power Technology Development Goals

3.4.2.2 Major Technical Challenges. This subarea includes efforts directed toward improved performance and cost of aircraft and missiles through the development of electrical power technologies. In the aircraft area, the primary thrust is focused on, highly reliable electrically-driven subsystems to replace reliability-plagued centralized hydraulics, pneumatics, and mechanically-driven engine gearbox subsystems. This concept integrates development of miniaturized power electronics, fault tolerant electric power distribution, long life energy storage, electric generators, electric motor drives/controllers, and electric actuator demonstrations. Weapon power for future megawatt class missions and military pulse power needs are also addressed. For rotary wing aircraft, the emphasis is on increasing power-to-weight ratio, reducing source noise, and increasing reliability of the large, main power transfer systems.

3.4.2.3 Related Federal and Private Sector Efforts. The electrically-based aircraft power program is coordinated with many related efforts across the government and in commercial industry. Some examples are the DoD IHPTET program, the Army's electric rotorcraft/tank programs, the Navy's electric ship and submarine programs, NASA's fly by light/power by wire programs, and the ARPA and DoE electric vehicle programs. The rotorcraft drive programs are conducted jointly between the Army and NASA Lewis Research Center. Industry IR&D programs in related areas totals over $51M.

3.4.3 S&T Investment Strategy

In executing aircraft power, focus is maintained on specific technology demonstrations, in order that the technology effort at the component level can be focused. National investment among the various technology demonstrations and technology development efforts are allocated with their potential payoff to warfighting needs and their relative contribution to achieving aircraft power goals.

3.4.3.1 Technology Demonstrations. There are four technology demonstrations in aircraft power. Three address the specific goals of aircraft power, and one the goals of rotorcraft drive. Objectives are to evaluate integrated component behavior in a realistic environments and to validate that the technology is sufficiently developed and understood to be transferred to new aircraft power/weapon power/rotorcraft drive developments and to improve existing aircraft power/weapon power/rotorcraft drive capabilities.

3.4.3.1.1 Power Management and Distribution for the More Electric Aircraft (MADMEL) Technology Demonstration—is one of three that addresses the needs of DTO AP.09.00.NF Aircraft Power (More Electric Aircraft). It develops a ground based demonstrator to integrate and test a 270 Vdc fault tolerant electrical power distribution system. System has immediate application to the F-22 and JAST aircraft.

3.4.3.1.2 Advanced Maintenance Free Aircraft Battery System Technology Demonstration—is one of three that addresses the needs of DTO AP.09.00.NF Aircraft Power (More Electric Aircraft). It will qualify, for flight, a battery and charger with built in test capability. Predecessor technologies were successfully transitioned to the B-52H fleet, and this advanced Maintenance Free Battery System will undergo flight demonstrations on the E-8/JSTARS program.

3.4.3.1.3 C-141 Electric Starlifter Technology Demonstration—is one of three that addresses the needs of DTO AP.09.00.NF Aircraft Power (More Electric Aircraft). It develops electric actuators and required electric power distribution to replace hydraulic-based flight control. A C-141, designated as the Electric Starlifter, is undergoing a 1000 hour, Reliability/Maintainability/Supportability-oriented, in-service flight test using electric aileron actuators to provide user confidence, and reliability data.

3.4.3.1.4 Rotorcraft Drive Technology Demonstrations—fulfill DTO AP.10.00.AN Rotorcraft Drive. They provide technologies required for very high power density rotorcraft drive systems. Development activities are also conducted to assess noise and reliability impacts.

3.4.3.2 Technology Development. Technology advances in all of the constituent areas of aircraft power/weapon power/rotorcraft drive are required to achieve the aircraft power goals. These constituent areas are represented by numerous individual technical efforts that are aimed at specific objectives that, if achieved, will collectively result in achievement of aircraft power goals, and are identified below:

3.4.3.2.1 Aircraft Power. This includes development of all required components for high power electronics, electrical machines, thermal control, applied electromagnetics, electrochemistry, and high temperature power semiconductor devices. The major advances required are achieving fault-tolerant power generation, electrical actuation, improving the overall electric systems reliability and replacing carcinogenic hydrazine in aircraft systems.

3.4.3.2.2 Rotorcraft Drives. This activity includes development of those component technologies required for very high power density rotorcraft drive systems, including gearing, bearings, housings, lubrication systems, and shafting. Major advances are required to significantly increase drive system power-to-weight, reduce drive system noise, and increase drive system reliability.

3.4.3.2.3 Weapon Power. This activity includes development of those component technologies required to produce megawatt pulse, airborne, missile, and air transportable ground power. Major advances are required to significantly increase power generation efficiencies while reducing power system weight and cost and increasing power system reliability.

3.4.3.3 Basic Research. Aircraft Power places a high priority on the quality, content, support, and successful conduct of basic research. The products of the basic research represent significant independent contributions to the national technology base, and are normally intended to achieve new knowledge and understanding, to develop and maintain technical expertise/capability, and to provide new options and approaches for future efforts. Current focus is in the areas of optical measurement techniques, plasma and discharge physics, high temperature magnetic materials, high power microwave, and high temperature superconductivity. Research is directed to support the development of a more electric aircraft.

3.5 High Speed Propulsion & Fuels

3.5.1 Warfighter Needs

Realizing the potential payoff for high speed airbreathing propulsion and high heat sink fuels will mark a major step increase in weapon system performance and cost effectiveness. High speed vehicle propulsion will be critical to meet worldwide requirements as we continue to reduce overseas forward basing. In the future, U.S.-based systems will provide long range, rapid response, virtual presence for time critical missions.

Ramjet missile propulsion systems will revolutionize air combat and surface strike areas. Ramjets nearly double missile engine total impulse over conventional solid rocket motors. As a result, several-fold improvements in aircraft air combat exchange ratios are attainable through revolutionary improvements in air-to-air missile kinematic capabilities such as increases in average missile velocity, launch range, no-escape range, and reduced time to autonomous range or target. Additionally, high speed strike missile concepts utilizing ramjets provide reduced time-to-target against hardened or deeply buried targets with up to 1000 nautical mile standoff ranges. Subsequent analyses have shown that the concepts provide a 30-fold increase in weapon effectiveness over existing systems.

Combined-cycle engine and scramjet propulsion systems offer enormous payoffs for future missile and aircraft. They address user-documented warfighting range, timeliness, and survivability deficiencies. Mach 6 cruise missiles will be able to attack targets from long and inherently safe stand-off ranges with flight times as short as one-seventh that of subsonic cruise missiles. Fast reaction stand-off theater weapons using Mach 8 hydrocarbon fueled scramjet engines will provide a rapid response weapon capability to counter highly mobile "SCUD-type" weapons from 300 nautical miles in less than 5 minutes or strike targets 1000 nautical miles away in 15 minutes. Mach 5 combined-cycle engines would enable tripling

unrefueled tactical aircraft ranges from 300 - 500 nautical miles to 1000 - 1500 nautical miles without increasing mission flight times. Future continental U.S. based combined-cycle engine and scramjet propelled Mach 10 aircraft could reach any military target in 2 hours. Other high payoff scramjet and combined-cycle engine applications include reusable single-stage and two-stage-to-orbit launch vehicles. Compared to rocket-powered systems, launch windows can be increased by an order of magnitude, 10 hours versus 1 hour, as well as improving ascent maneuverability and launch flexibility for military surveillance missions.

High heat sink fuels such as JP-8+100 will significantly reduce aircraft and engine fuel system maintenance costs incurred due to fuel fouling/coking. JP-8+100 will also provide additional heat sink and thermal stability for future systems. Endothermic hydrocarbon fuels offer solutions for significant improvements in aircraft thermal management which will enable sustained flight in the Mach 5-8 regime. Ultimately, high heat sink hydrocarbon fuels enable the use of a single high temperature capable jet fuel that eliminates fuel system deposits and related maintenance and is applicable to both air and ground vehicles operating throughout all engine cycle temperatures and air vehicle speeds

3.5.2 High Speed Propulsion & Fuels Overview

3.5.2.1 Goals and Timeframes. High speed propulsion and fuels technology programs will achieve the goals shown in Figure I.9. High speed propulsion goals are referenced to the demonstrated state-of-the-art for three engine classes: ramjet (RJ) for missile applications, scramjet (SCRJ) for missiles and air vehicles, and combined-cycle engine (CCE) for manned/unmanned vehicle. Fuel goals are referenced to high heat sink hydrocarbon fuels (HHSH/CF) for improved fuel thermal stability and air vehicle thermal management cooling capability.

1997	RJ	+100% effective impulse via a variable flow ducted rocket (VFDR)
1998	HHSH/CF	+100°F thermal stability, +50% heat sink (JP-8+100)
1999	RJ	M=3.5/4.0 low cost missile ATD
2000	CCE	+30% specific thrust, +20% thrust/weight
2001	SCRJ	Freejet demonstration, Isp=850 sec, specific thrust = 60 lb_f/lb_m/sec @ M=8
2005	HHSH/CF HHSH/CF	5X increase in fuel cooling capacity (JP-900) 5-10X increase in fuel cooling capacity (endothermic fuels)

Figure I.9. High Speed Propulsion & Fuels Technology Development Goals

3.5.2.2 Major Technical Challenges. The challenge is to develop critical enabling hypersonic technologies required to support the development of hypersonic weapon systems and high heat sink fuels for all services. Required are simple, reliable high performance inlets (including airframe-integrated inlets); combustors that deliver optimum performance for ramjets, scramjets, and combined-cycle engines; nozzle/expansion systems that provide thrust over the entire range of vehicle operation; validated high temperature structural design methods, thermal loads, and materials and fabrication processes for propulsion flowpath components operating for extended periods above Mach 4; and additives for fuels to suppress auto-oxidation and degradation mechanisms while maximizing available energy and providing adequate airframe cooling.

3.5.2.3 Related Federal and Private Sector Efforts. NASA has research efforts in combined-cycle engines and scramjets that are closely coordinated and/or integrated with DoD. NASA and DoD participate jointly in the development of combined-cycle engine and scramjet propulsion systems. To address Congressional concerns regarding future fuel availability, DoD is working cooperatively with the Department of Energy to develop high temperature, thermally stable and endothermic fuels from coal.

3.5.3 S&T Investment Strategy

In executing this subarea, focus is maintained on specific technology demonstrations, in order that the technology effort at the component level can be focused. National investment among the various technology demonstrations and technology development efforts are allocated with their potential payoff to warfighting needs and their relative contribution to achieving High Speed Propulsion and Fuels goals.

3.5.3.1 Technology Demonstrations. The integrated propulsion system technology demonstrators are divided into three families: ramjets, scramjets, and combined-cycle engines. High heat sink hydrocarbon fuel demonstrations are integrated into applicable engine demonstrators. The knowledge obtained from the demonstrators will provide additional direction for all future exploratory efforts. Additionally, the results will enable the confident transition of technology.

3.5.3.1.1 Ramjet Technology Demonstrations—fulfill DTO AP.11.00.NF High Speed Propulsion. The major challenge is demonstrating propulsion system performance over representative flight envelopes and flight profiles. Ramjet component technology is initially ground demonstrated individually in booster and sustainer

testing and then integrated into full engine ground testing. Upon completion, the engine is flight tested for final proof of performance.

3.5.3.1.2 Scramjet Technology Demonstrations—fulfill DTO AP.12.00.F Hydrocarbon Scramjet Missile Propulsion. The major challenge is demonstrating integrated scramjet system performance over representative flight envelopes and flight profiles. Scramjet demonstrator engines will be built upon exploratory development work in the area of storable fuel dual mode ramjet/scramjet technology and will include both sub- and full-scale ground test engines using endothermic hydrocarbon fuels.

3.5.3.1.3 Combined-Cycle Engine Technology Demonstrations—fulfill DTO AP.11.00.NF High Speed Propulsion. Demonstrating integrated low and high speed operation and performance as well as transition to and from these conditions is the major technical challenge. The IHPTET initiative will provide enabling technologies in turbomachinery propulsion components, materials, thermal management, and controls.

3.5.3.1.4 High Temperature Fuels Technology Demonstrations—fulfill DTO AP.13.00.F High Temperature Fuels. They are conducted using laboratory rigs, engine component simulators, and reduced scale fuel system/engine simulators. Further testing is conducted in sea level engine testing culminating with a flight test.

3.5.3.2 Technology Development

3.5.3.2.1 Air Induction Systems. The air induction system consists of the engine air inlet and the internal compression region to the interface with the engine. Major advances are required to increase overall inlet pressure recovery while reducing system length and weight, and attaining acceptable flow quality, distortion and turbulence at the combustor entrance.

3.5.3.2.2 Combustors/Ramburners. This system includes ramjet/ combined-cycle engine ramburner/augmentor, and scramjet combustion systems. Major advances are required to significantly increase combustion efficiencies, increase combustor operability range, and develop technologies to improve fuel vaporization, fuel kinetics, combustor piloting and flameholding, and controlled heat release.

3.5.3.2.3 Nozzle/Expansion Systems. This area includes single expansion ramp and conventional axisymmetric nozzles. Future exhaust system technology needs include lightweight high-temperature nozzle materials and structures, advances nozzle cooling techniques, increased nozzle efficiencies, and high levels of vehicle integration.

3.5.3.2.4 Fuels and Fuel Systems. This area includes JP-8+100, JP-900, and endothermic fuels for aircraft and high speed propulsion systems and the associated fuel delivery systems. Major advances are required to increase fuel thermal stability, improve fuel cooling capability, increase fuel energy density, and reduce system weight and cost.

3.5.3.2.5 Structures and Materials. This area includes structural design methods, thermal loads, and material and fabrication processes for flowpath components of high speed propulsion systems. Major advances are required to validate the structural integrity and environmental tolerance of the principal flow path components of high speed propulsion systems, such as actively cooled panels, cowl/strut leading edges, fuel injectors, and seals, to operate for extended periods above Mach 4.

3.5.3.3 Basic Research. High Speed propulsion and Fuels places a high priority on the quality, content, support, and successful conduct of basic research. The products of the basic research represent significant independent contributions to the national technology base, and are normally intended to achieve new knowledge and understanding, to develop and maintain technical expertise/capability, and to provide new options and approaches for future efforts. Current focus is in the areas of combustion, supercritical fuels, vapor phase lubricant mechanisms, and ramjet and scramjet propulsion.

4. TECHNOLOGY AREA ROADMAPS AND RESOURCES

4.1 TECHNOLOGY AREA ROADMAPS

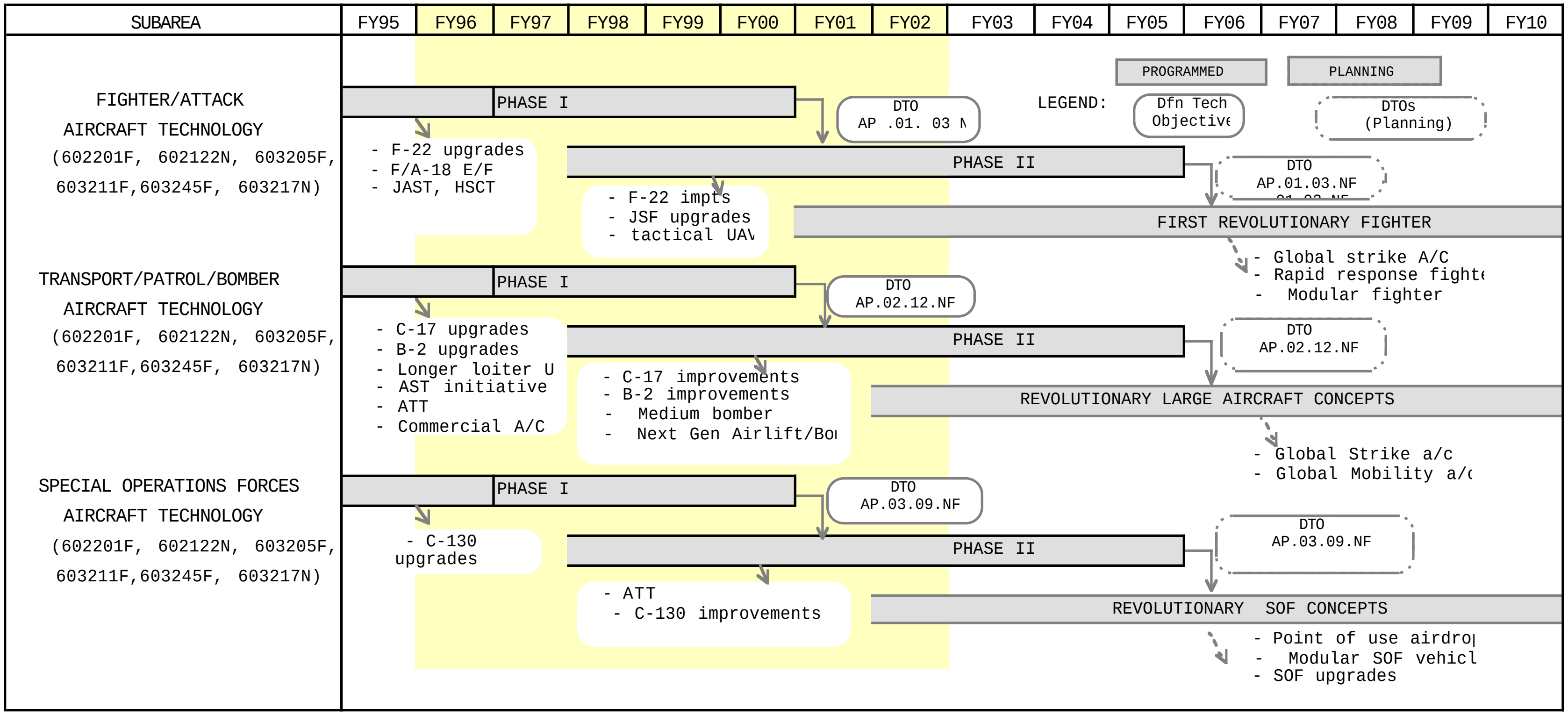


Figure I.10. Fixed Wing Vehicles

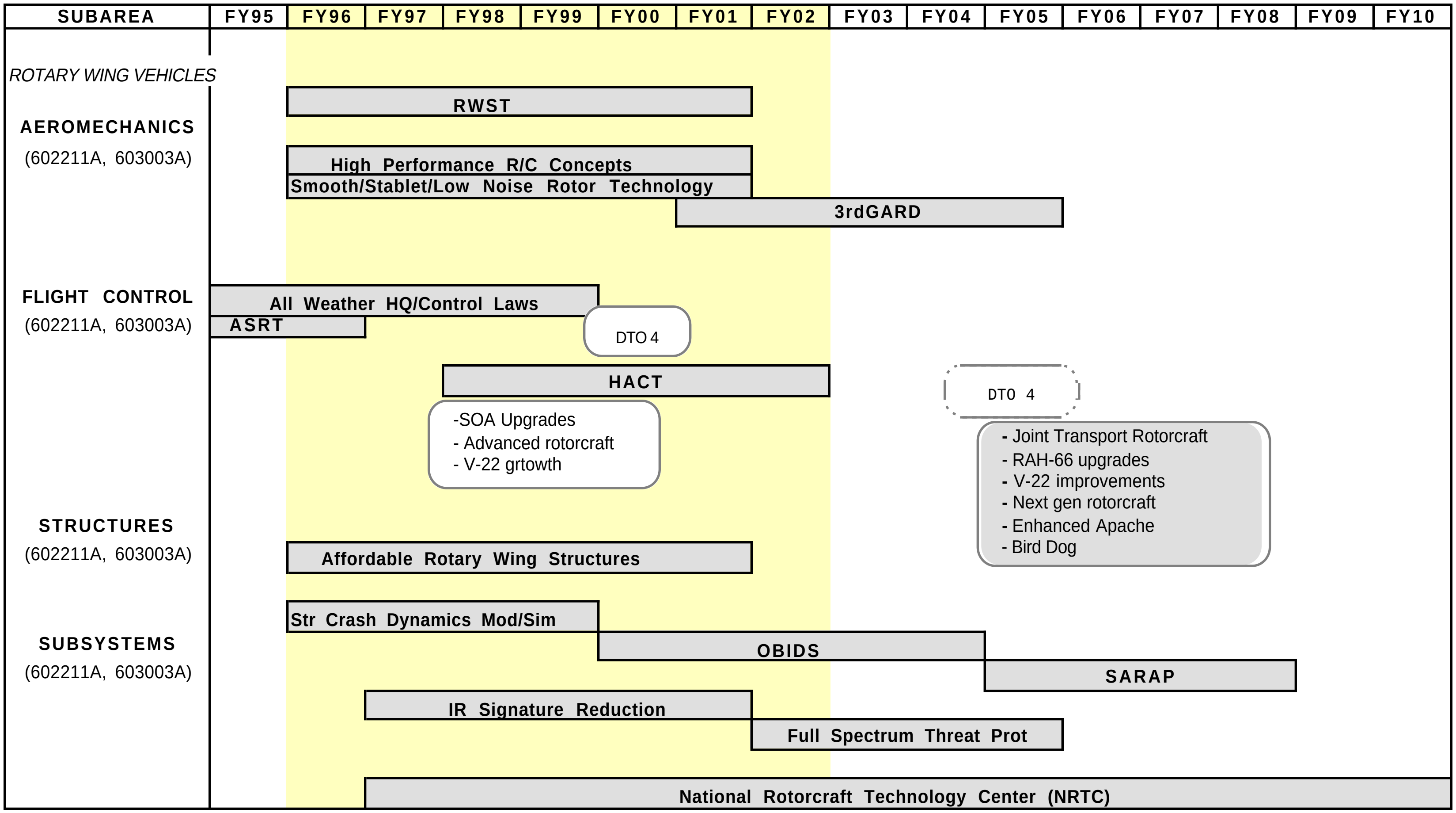


Figure I.11. Rotary Wing Vehicles

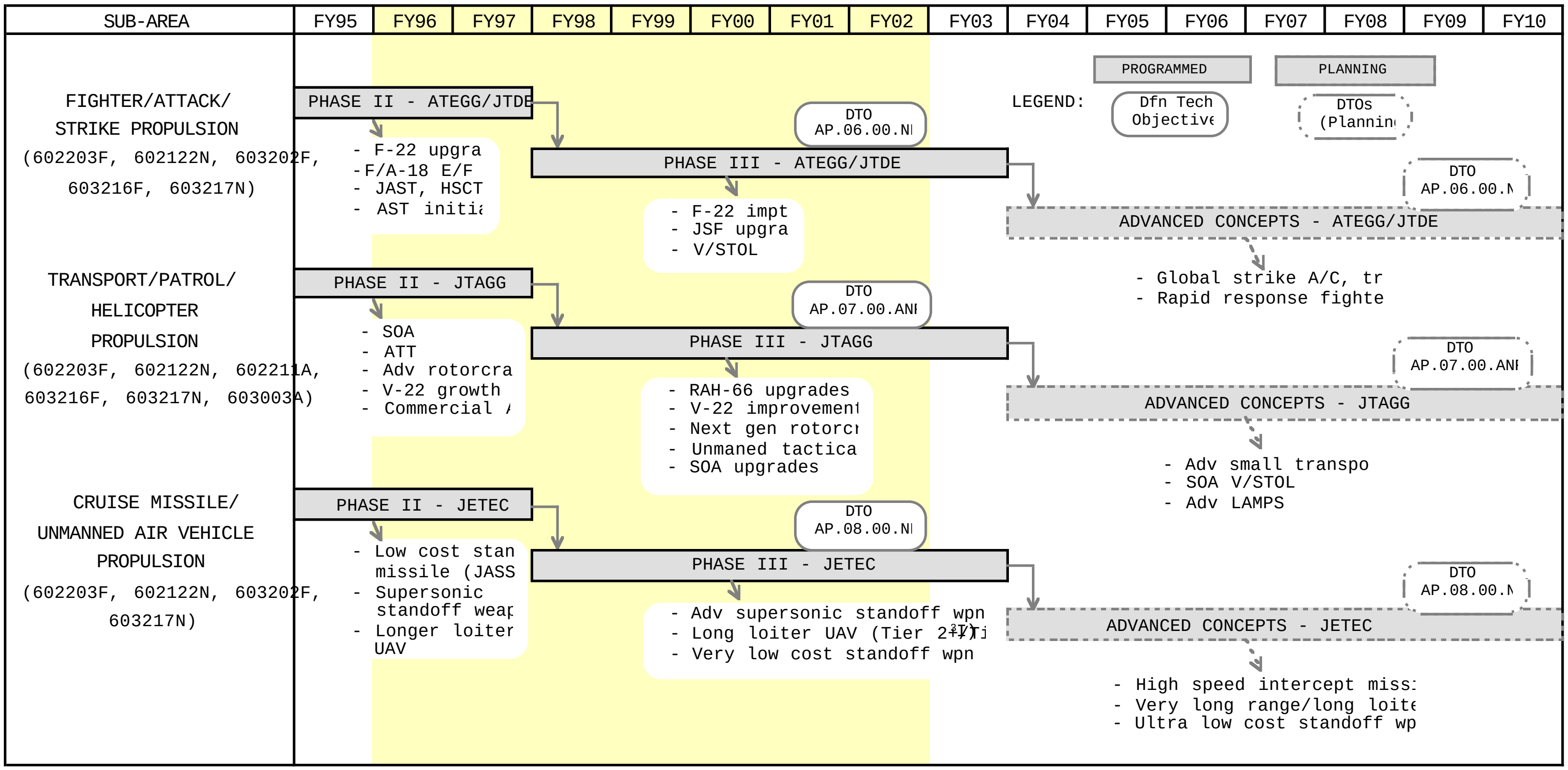


Figure I.12. Integrated High Performance Turbine Engine Technology

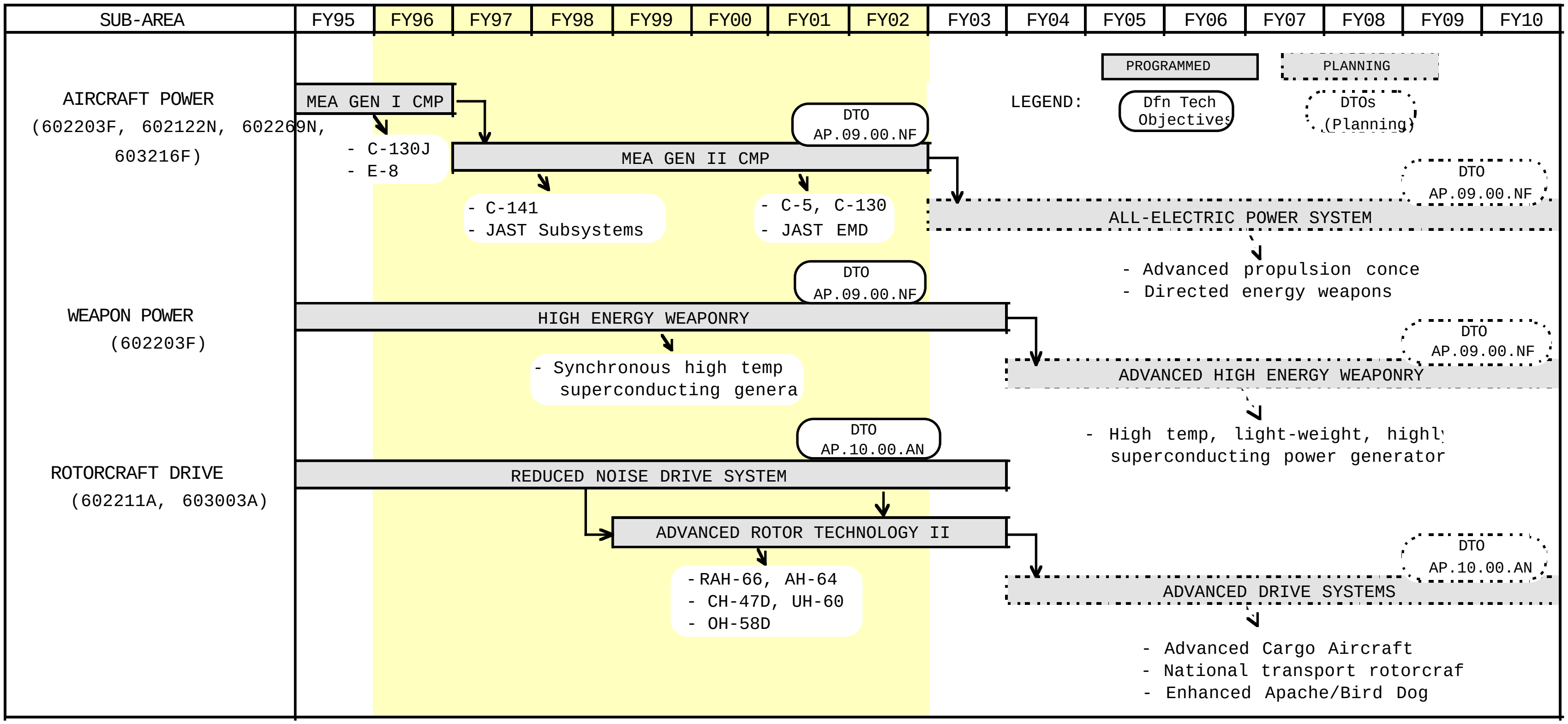


Figure I.13. Aircraft Power

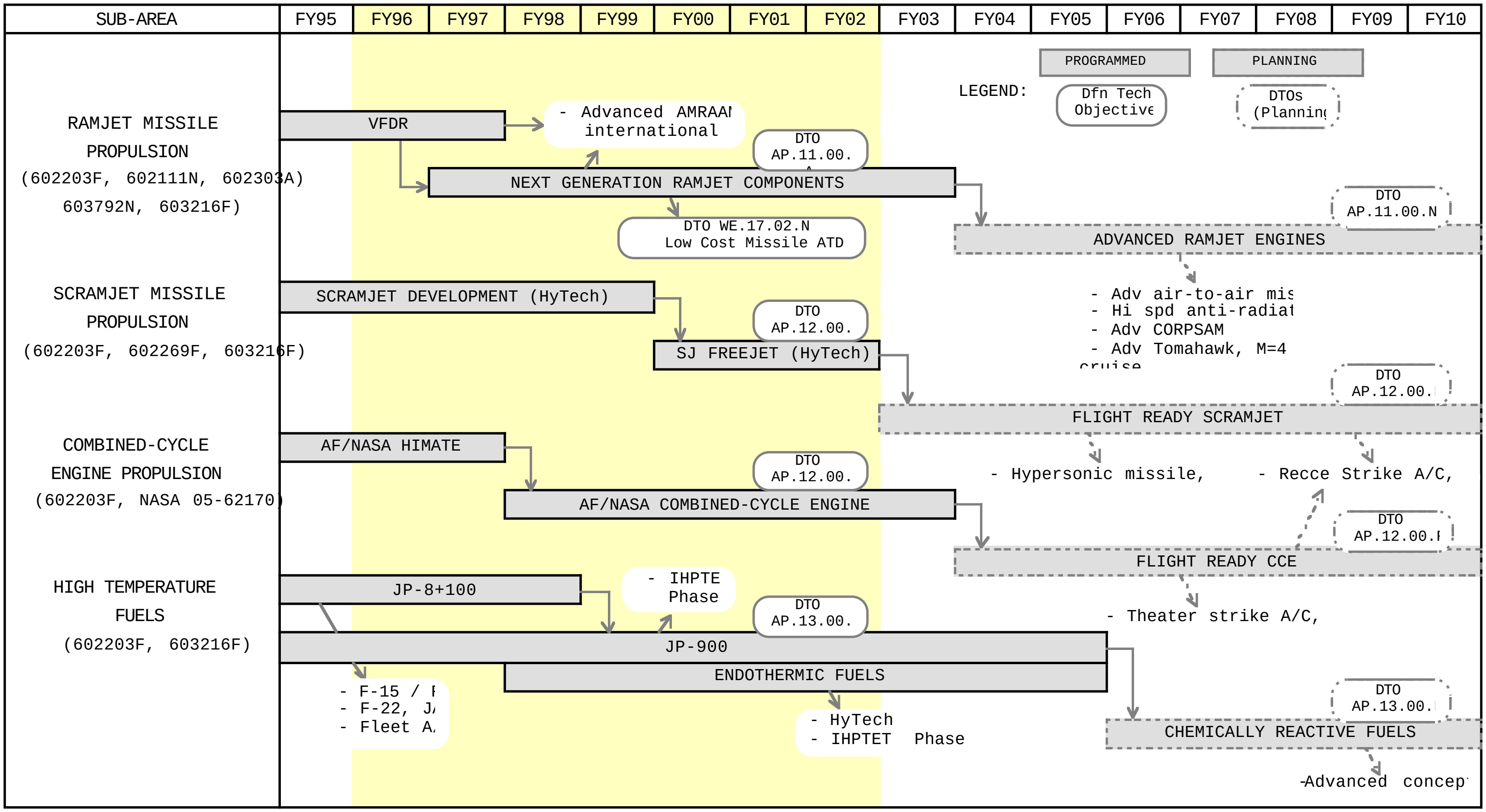


Figure I.14. High Speed Propulsion & Fuels

4.2 Air Platforms Technology Area Resources ($M)

DTOs	Program Element	$ in millions FY1996	FY1997	FY1998	FY1999	FY2000	FY2001
AP.01.03.NF Fighter/Attack Aircraft Technology	0602201F	33.2	35.7	36.8	38.4	39.4	41.6
	0602702E	10.2	13.7	18.5	16.2	16.2	13.8
	0602712E	1.5	4.9	3.7	1.7	2.2	2.3
	0602122N	3.5	4.5	5.2	6.4	6.5	6.4
	0603217N	1.8	--	0	0	0	0
	0603205F	4.7	3.8	3.3	3.8	4.2	4.3
	0603211F	4.0	3.2	5.3	5.6	5.2	4.8
	0603245F	7.4	4.0	6.4	6.2	6.3	7.0
	0603800E	29.8	78.3	23.9	0	0	0
	DTO TOTAL	96.0	148.1	103.1	78.3	80.0	80.3
AP.02.12.NF Airlift/Patrol/Bomber Aircraft Technology	0602201F	12.3	13.2	13.7	14.2	14.6	15.4
	0602122N	1.7	2.2	2.5	3.1	3.2	3.1
	0603217N	0.9	0	0	0	0	0
	0603205F	1.8	1.4	1.2	1.4	1.6	1.6
	0603211F	1.5	1.2	2.0	2.1	1.9	1.8
	0603245F	2.7	1.5	2.4	2.3	2.3	2.6
	DTO TOTAL	20.8	19.5	21.7	23.1	23.6	24.5
AP.03.09.NF Special Ops. Forces Aircraft Technology	0602201F	8.0	8.6	8.9	9.3	9.5	10.1
	0602122N	0.8	1.1	1.3	1.5	1.6	1.6
	0602702E	0	0.2	0	0	0	0
	0603217N	0.4	0	0	0	0	0
	0603205F	1.1	0.9	0.8	0.9	1.0	1.0
	0603211F	1.0	0.8	1.3	1.3	1.3	1.2
	0603245F	1.8	1.0	1.5	1.5	1.5	1.7
	DTO TOTAL	13.2	12.6	13.8	14.6	14.9	15.5
AP.04.00.AN Helicopter Active Control Technology (HACT)	0603003A	--	--	0.5	3.5	10.0	9.0
	DTO TOTAL	0	0	0.5	3.5	10.0	9.0
AP.06.00.NF Fighter/Attack/Strike Propulsion	0602203F	34.1	38.2	38.5	39.2	39.9	41.0
	0603202F	22.8	22.6	24.9	24.9	25.7	26.9
	0603216F	28.7	30.3	29.4	30.3	31.2	34.3
	0602122N	3.6	4.0	4.6	4.6	4.6	4.6
	0603217N	4.3	7.5	5.8	5.0	5.0	7.4
	DTO TOTAL	93.5	102.6	103.1	104.0	106.4	114.2

Figure I.15. Air Platforms Technology Roadmap Resources

TOTALS MAY NOT AGREE DUE TO ROUNDING

DTOs	Program Element	$ in millions					
		FY1996	FY1997	FY1998	FY1999	FY2000	FY2001
AP.07.00.ANF	0602203F	2.2	2.3	2.4	2.4	2.5	2.6
Transport/Patrol/	0603216F	1.5	1.0	1.0	2.0	2.0	2.0
Helicopter Propulsion	0602122N	1.2	1.3	1.5	1.5	1.5	1.5
	0603217N	2.2	1.2	2.0	2.9	3.5	3.0
	0602211A	1.8	2.3	2.2	2.3	2.2	2.4
	0603003A	6.8	7.8	6.6	6.6	7.2	7.1
	DTO TOTAL	15.7	15.9	15.7	17.7	18.9	19.6
AP.08.00.NF Cruise Missile/	0602203F	4.4	4.6	4.7	4.8	4.9	5.1
Unmanned Air Vehicle	0603202F	5.5	5.7	4.0	5.0	5.0	5.0
Propulsion	0602122N	1.2	1.3	1.5	1.5	1.5	1.5
	0603217N	1.3	1.1	2.3	3.4	3.1	1.5
	DTO TOTAL	12.4	12.8	12.6	14.7	14.6	13.2
AP.09.00.NF Aircraft Power	0602203F	15.2	15.0	15.5	15.3	15.3	16.1
(MEA)	0603216F	2.6	2.7	5.4	5.4	5.8	5.8
	0602122N	0.6	0.7	0.6	0.8	0.8	0.8
	0602269N	0.4	0.4	0.4	0.4	0.4	0.4
	DTO TOTAL	18.9	18.8	21.9	21.9	22.3	23.1
AP.10.00.AN Rotorcraft Drive	0602211A	0.4	0.4	0.5	0	0	0
	0603003A	1.7	2.0	4.0	9.0	7.0	0
	DTO TOTAL	2.1	2.4	4.5	9.0	7.0	0
AP.11.00.FN High Speed	0602203F	7.7	7.4	7.4	6.9	7.1	7.8
Propulsion	0603216F	4.5	2.3	1.6	1.6	1.7	1.7
	0602111N	0.9	0.5	0.2	1.0	1.5	1.5
	0602303A	1.5	1.7	0	0	0	0
	DTO TOTAL	14.6	11.8	9.1	9.5	10.3	11.0
AP.12.00.F Hydrocarbon Scramjet	0602269F	18.4	7.5	18.5	16.7	16.7	17.8
Missile Propulsion (HyTech)	DTO TOTAL	18.4	7.5	18.5	16.7	16.7	17.8
AP.13.00.F High Temperature	0602203F	8.7	7.4	6.9	6.9	6.9	7.3
Fuels	0603216F	2.3	1.9	1.9	2.0	2.0	2.0
	DTO TOTAL	11.0	9.3	8.9	8.8	8.9	9.3

Figure I.16. Air Platforms Technology Roadmap Resources
TOTALS MAY NOT AGREE DUE TO ROUNDING

AIR PLATFORMS
ACRONYMS

AAW	Active Aeroelastic Wing
ACTIVE	Advanced Control Technology for Integrated Vehicles (F-15 testbed)
AST	Advanced Subsonic Technology
ASTER	Advanced Structures Technology for Efficient Rotorcraft
ATD	Advanced Technology Demonstration
ATEGG	Advanced Turbine Engine Gas Generator
CCE	Combined-Cycle Engine
DoD	Department of Defense
DTO	Defense Technology Objective
ERD	Extended Range Demo
EXP	Expendable Engine
FAA	Federal Aviation Administration
FWV	Fixed Wing Vehicles
GLCC	Great Lakes Composite Consortium
HACT	Helicopter Active Control Technology
HHSH/CF	High Heat Sink Hydrocarbon Fuels
HSCT	High speed Civil Transport
HSR	High-Speed Research
IHPTET	Integrated High Performance Turbine Engine Technology
IR	Infra-Red
IR&D	Independent Research & Development
IRAD	Independent Research and Development
JCS	Joint Chiefs of Staff
JETEC	Joint Expendable Turbine Engine Concepts
JTAGG	Joint Turbine Advanced Gas Generator
JTR	Joint Transport Rotorcraft
LO	Low Observable
MADMEL	Power Management and Distribution for the More Electric Aircraft
MATV	Multi-Axis Thrust Vectoring
MEA	More Electric Aircraft
MOA	Memorandum of Agreement
NASA	National Aeronautics and Space Administration
O&S	Operation and Support
OCR	Operational Capability Requirements
R&D	Research and Development
RF	Radio-Frequency
RJ	Ramjet
RWV	Rotary wing Vehicles
S&T	Science & Technology
SBIR	Small Business Innovative Research
SCRJ	Scramjet
TD	Technology Demonstration
TDA	Technology Development Approach
TF/TJ	Turbofan/Turbojet
TS/TP	Tuboshaft/Turboprop

TTCP	The Technical Cooperation Program
USA	United States Army
USAF	United States Air Force
USMC	United States Marine Corps
USN	United States Navy
VFDR	Variable Flow Ducted Rocket
VISTA	Variable In-Flight Stability Aircraft (NF-16 testbed)

II. FY 1997 DEFENSE TECHNOLOGY AREA PLAN FOR CHEMICAL, BIOLOGICAL DEFENSE AND NUCLEAR

1. INTRODUCTION

In recent years, proliferation of Weapons of Mass Destruction (WMD), specifically chemical, biological and nuclear weapons, has increased. In response to this danger, the Joint Chiefs of Staff designated Counterproliferation of WMD as one of the top five Future Joint Warfighting Capabilities. Developing effective capabilities to deal with WMD proliferation threats is also a key element of U.S. strategy, as articulated by the President in The National Security Strategy of the United States (February 1996, pp. 19-21). The bipolar warfighting scenarios which permeated our Cold War strategy in Central Europe have given way to a new force projection strategy, and U.S. forces must be prepared for conflict in a Chemical-Biological & Nuclear (CB&N) warfare environment in a Global Reach concept. Developing the required capability to project military power to unprepared battlefields has led to a fundamental change in the S&T requirements for the CB&N community. The ready availability of CB and nuclear radiological weapons has expanded the WMD threat spectrum from the traditional organized enemy force to include amorphous threats such as terrorism.

1.1 Definition/Scope

The Chemical, Biological Defense and Nuclear Technology Area is devoted to the development of technology to counter the threat of WMD and to ensure the safety and mission effectiveness of U.S. forces. This technology area is subdivided into non-medical Chemical and Biological Defense (CB Defense), and Nuclear program areas, with eight subareas as shown in Figure II.1. Medical CB Defense technology efforts are included in Chapter VI, Medical and Biomedical. Additional information can also be found in the Joint Warfighting Science and Technology Plan (JWSTP), Chapter IV, sections J and L. See Resource Appendix for funding of this Defense Technology Area.

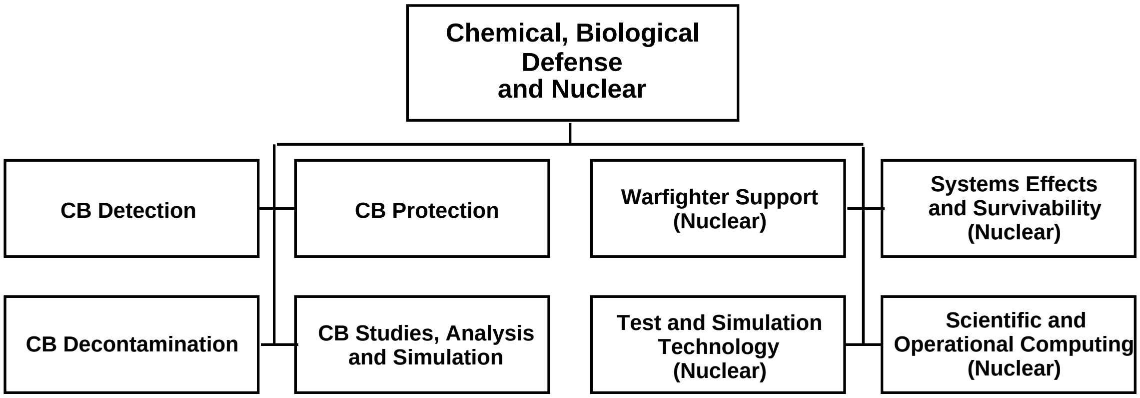


Figure II.1. Planning Structure - Chemical, Biological Defense and Nuclear

1.2 Strategic Goals

The strategic goal of CB Defense is the seamless integration of technologies from its four subareas—detection, protection, decontamination, and studies, analysis and simulation—into a system of systems for horizontal integration across the spectrum of combat and support systems. The basic and primary concept of operations is early detection and warning to provide situational awareness and permit forces to avoid the threat. The detection capability will enable commanders to activate/deactivate protective/avoidance measures in a timely fashion. This capability can be provided by a real-time sensor network to detect, identify, map, quantify, monitor, and disseminate information on the presence of CB warfare and radiological threats at/below incapacitating/physiological effect levels in the operational theater.

When avoidance is not possible, integrated protection for CB warfare will allow U.S. forces to maintain operational effectiveness in a contaminated environment with minimal impact on logistics. Decontamination may be required in CB warfare conflicts, especially for personnel, mission essential assets and areas, as well as for retrograde and resupply operations.

The entire CB Defense strategic goal is supported by studies, analysis and simulation which supports each of the other three CB Defense subareas and aids in the assessment of Joint Service doctrine, training and materiel development, equipment design, and enables commanders to integrate and interpret real-time data.

The goal of the Nuclear program area is to provide technologies needed for an effective, survivable nuclear force that will contribute to the national goal of deterring the threat or use of nuclear weapons. A complementary objective of this program area is to ensure that forces and equipment, especially C4I systems, are protected against the effects of a nuclear weapon detonation, e.g., transient radiation effects on electronics (TREE) and total neutron dosage. The technologies being developed under this area are designed to prevent such disruptions through the development of radiation-tolerant microelectronics for satellites, as well as the development of affordable, integrated protection of ground-based C4I systems, including those that use off-the-shelf equipment.

1.3 Acquisition/Warfighting Needs

The objective of the CB Defense and Nuclear (or NBC) technology program is to enable our forces to survive, fight and win in an NBC warfare environment by ensuring a superior defensive posture which protects our forces and equipment, and makes CB or nuclear warfare a high risk, low payoff alternative for opposing forces.

To achieve this objective, the warfighter needs to be able to detect, protect, and decontaminate CB warfare and radiological threats with minimal logistics burdens. Chemical detection sensors would be integrated into a variety of platforms ranging from individual battledress to autonomous reconnaissance systems. All of these detection capabilities must be integrated to provide a cohesive picture of the operational theater through the use of information technologies, such as simulation, to provide operational commanders with the required situational awareness needed for command decisions.

Protection applications range from personal ensembles to filtration systems for vehicles and large-area enclosures, including ships and command posts. Ensembles and respiratory protection that will minimize physiological and psychological burdens are required to maintain peak operational performance capabilities for individual warriors. New materials and filtration systems are needed to reduce the logistics burden for ground vehicles, ships, aircraft and large-area enclosures. Decontamination capabilities are required to sustain operations in a contaminated environment, to clean up personnel and wide areas, for retrograde and resupply operations and to reconstitute individual equipment, vehicles, sensitive equipment, and weapons platforms.

Chemical and Biological Defense and Nuclear technology development responds directly to the Counterproliferation and CB Warfare Detection required operational capabilities identified in the JWSTP and in the national report on these activities, as submitted to Congress in May 1995 by the Counterproliferation Program Review Committee. In confrontations involving WMD proliferants, personnel and systems must be survivable; similarly, effective nuclear forces are required to support deterrence both prior to and during conflicts. The recent Tokyo subway attack is an example of new threat scenarios we are likely to encounter in the future given the ready access to CB and radiological weapons by Third World and terrorist organizations.

The CB Defense and Nuclear technology area plays an important supporting role for other technology areas. Additional JWSTP objectives involve applications of electronic, optical, and computer technologies (e.g., for Information Superiority, Precision Force, Combat Identification, Information Warfare, Joint Theater Missile Defense, and Electronic Warfare). CB Defense and Nuclear technology development ensures that the critical systems employed can accomplish their missions if proliferants employ WMD. Some examples of CB Defense and Nuclear Transition Opportunities can be seen in Figure II.2. This technology base also provides much of our capability to model the propagation of signals and information within weapon-effect-disturbed environments.

Subarea	Current Baseline	5 years	10 years	15 years
CB Detection	• Limited number of detectable agents, multiple point sensors • Interim Biological Detection System • Chemical detection from 1-5 km • Aerosol detection from 30 km • Voice alerts • Limited availability of digitized data; analog communications	• Multiple detectable agents, fewer point sensors • Ultra-low dose chemical interior monitor • Automated point biodetection system • Early Warning Bio-aerosol detection from 1-5 km • Early Warning Aerosol Cloud detection to 50 km • Availability of digitized data • Global access of CB data • Joint warning and reporting network	• CB water and surface contamination monitor • Small lightweight chemical monitor • Man-portable point biodetection system • Chemical detection from 20 km • Early Warning Bio-class aerosol detection • Early Warning Aerosol Cloud detection to 100 km • Real-time data and time-projection access for operational theater • Limited access to virtual reality	• Man-portable integrated CB detection system • Chemical sensor integrated into clothing • Early Warning Chemical and biological aerosol detection • Global access to virtual reality of operational theater
CB Protection	• Battle dress overgarment, butyl gloves, vinyl overshoes • M40 and MCU-2/P Masks; C2 canister • Single-pass carbon CP filters	• Ltwt garments and breathable gloves • Improved agent resistance, vision, and compatibility; lower breathing resistance and bulk/weight • Improved filter life • Regenerative filtration for armored vehicles	• Low cost, ltwt garments • CB duty uniform 50% lighterweight than JSLIST I uniform/overgarment • Integrated helmet/ respirator with visor display, positive pressure breathing, compatibility with weapons sighting systems • Non-carbonaceous CP filtration	• Integrated duty uniform with CB and environmental protection, signature reduction, decontaminable for reuse • Hybrid CP systems
CB Decontamination	• DS2, STB and improved sorbent technologies	• DS2 replacement • Concepts for aircraft interior decon • Concepts for wide area/fixed site decon	• Supercritical fluid-based decon for sensitive equipment; •Demo enzymatic decon	• Strategic modular decon systems and approaches
CB Studies, Analysis and Simulation	• Transport and diffusion models with terrain features	• Microgeography and micrometeorology for CB hazard prediction • Collateral effects predictor • CB effects into simulators • Trade-off models to assess value added of CB capabilities	• Real-time computation of hazards • Virtual reality simulators	
Warfighter Support (Nuclear)	• Refocusing of capabilities to respond to proliferation threats underway	• Demonstrate and validate initial adaptive planning for counterproliferation	• Complete initial dual-revalidation of nuclear stockpile in collaboration	• Continuous adaptation to new requirements as identified by CINCs
Systems Effects and Survivability (Nuclear)	• In process of identifying what must be done to adapt to new, post-cold war, protection requirements	• By FY98, qualify production ready radiation tolerant 4M SRAM	• By FY00, demo radiation tolerant 100k gate array and 16M SRAM using 0.35 micron SOI technology	• Adaptation of survivability practices to respond to future threats and to take advantage of new technologies
Test and Simulation Technology (Nuclear)	• Consolidation and refocusing on new requirements; incremental improvements to existing capabilities	• IOC for LB/TS with non-ideal airblast simulation capability and implement initial component of new DECADE radiation simulator	• Adapt investment strategy to take advantage of technical progress, e.g., new laser sources	• Take advantage of developments in advanced physics programs, e.g., favorable results from National Ignition Facility
Scientific and Operational Computing (Nuclear)	• Current generation super-computer	• Transition to HPC architecture and departmental machines	• Interface with ASCI; more emphasis on virtual experiments supported by physics understanding	• TBD - timeframe approximates 7+ generations of change in base technologies

Figure II.2. CB Defense and Nuclear Technology Transition Opportunities

2. DEFENSE TECHNOLOGY OBJECTIVES (DTOs)

CB.01.10-D Integrated Biodetection ATD

CB.02.10-D Joint Warning and Reporting Network (JWARN)

CB.03.10-D Integrated Chemical and Biological Sensor Suite

CB.04.10-D Joint Service Chemical Miniature Agent Detector (JSCMAD)

CB.05.10-D (not used)

CB.06.12-D Advanced Lightweight Chemical Protection

CB.07.10-D Laser Standoff Chemical Detection Technology

CB.08.12-D Advanced Agent Filtration

CB.09.12-D Decontamination for Global Reach

CB.10.07-H Nuclear Technology Development

CB.11.07-H Planning Systems for Contingencies Involving Proliferants

CB.12.01-H Electronic System Radiation Hardening

CB.13.07-H Hard Target Defeat

CB.14.07-H Prediction and Mitigation of Collateral Hazards

CB.15.01-H Balanced Electromagnetic Hardening Technology

3. TECHNOLOGY DESCRIPTIONS

3.1 CB Detection

3.1.1 Warfighter Needs

The combat efficiency of forces can be increased by reducing the physiological and psychological effects of operating in a CB contaminated environment by possessing the ability to constantly monitor for the presence of CB warfare agents. Information provided by a CB warfare agent detection network that can detect, identify, map, quantify, and track the threat in the operational theater will provide commanders the situational awareness necessary for command decisions. A “real-time” detection network composed of chemical sensors integrated into individual battledress, weapon platforms, and stand-alone units linked to the C3I system will process and integrate sensor data with geographical, meteorological, and intelligence data to provide an up-to-date and time-projected CB warfare situational threat analysis. The network will provide situational awareness on different levels depending on the need.

3.1.2 CB Detection Overview

3.1.2.1 Goals and Timeframes. The goal of the Detection subarea is to provide a real-time capability to detect, identify, map, quantify, track, and disseminate information on the presence of all CB warfare agent threats at levels below incapacitation/physiological significant effects. Current emphasis is on multi-agent sensors for CB point and early warning detection. To meet the needs of the next 3 to 5

years, a number of sensors targeted against either chemical or biological agents are being developed while detection technology matures. In particular, a pocket-sized chemical vapor point detector and an automated biological point detector will be available in this timeframe. In the near-term, a selection between competing point chemical detection technologies (ion mobility spectroscopy vs. surface acoustic wave) will be made in order to transition one out of tech base for development as a fielded system. Similarly during the near-term, a decision on the optimal technological approach for early warning of chemical and biological threats (remote vs. standoff) will be made. Far term objective technologies will focus on the integration of chemical and biological detection into a single sensor suite.

3.1.2.2 Major Technical Challenges. The CB Defense technology area includes a number of different technologies; they range from analytical and materials characterization techniques such as various forms of spectroscopy and bioassay technologies, materials development, to engineering concepts and information technology (computer/communication hardware and software). The technical challenges are to enhance sensitivity and selectivity, increase number of detectable CB agents, decrease response time, enhance sampling techniques, discriminate from naturally occurring background materials, develop advanced signal processing for detection algorithms, reduce size, weight and power requirements, integrate data with threat models, integrate sensor systems into C3I system, increase computational/communication capabilities, reduce cost, and minimize logistical requirements.

This is being accomplished by the development of new immunoassay systems, deoxyribonucleic acid (DNA or genetic) probes, materials for coatings, infrared/ultraviolet (IR/UV) lasers, mass spectrometric technologies for biologicals as well as chemicals, improvements in previously explored technologies such as surface acoustic wave technology, non-radioactive ionization sources, optics, and pre-concentrators, and nonspecific concepts/strategies like whole cells as a detector, naturally occurring chemical markers in biological materials, enhanced Raman spectroscopy techniques for liquid contaminants on surfaces or contaminants in water, or sampling techniques for collection or introduction into various point detection systems and efforts to understand and characterize biological/chemical/physical properties and physiological effects of CB agents. In addition, technologies are being explored for micromechanical fluidics technologies for sample processing and for imbedding separation and identification technologies in chip-sized devices.

Process and materials engineering, thermal management, component integration, fluidics management and other new engineering concepts are reducing system size, weight, power, and response time and optimizing detector configurations and logistical requirements. These new engineering concepts combined with the efforts in the fundamental sciences are producing advances in technology such as IR/UV detectors that are more uniform, have higher sensitivity and efficiency, and function under conditions close to ambient temperatures instead of -200°C, new lasers that have high outputs, use less power, smaller in size and weight, and have wider frequency ranges, and selective sampling systems that are more efficient.

The information technologies are responsible for developing new signal processing techniques to analyze sensor data and integrating the information to the threat models along with geographical, meteorological and intelligence data for dissemination

in the C3I system. The information technologies must be able to handle a tremendous amount data, both for processing and manipulation through the network. The CB Defense technology area is responsible for the development/advancement of software algorithms for pattern recognition, signal processing, artificial intelligence, expert systems, virtual 3-D simulations, and the computer/human interface. The actual computational/communication hardware (design of computer/electronic chips) are outside the scope of the CB Defense technology area.

3.1.2.3 Related Federal and Private Sector Efforts. Chemical and biological detection is a specialized subset of a much larger environmental health and safety area. All CB detection technology, in principal, can be modified to address the larger picture of environmental health and safety. The ability to detect, identify, map, monitor, quantify, and track industrial hazardous and medically infectious materials is considered highly desirable by the commercial sector. The potential benefits of dual-use for the CB detection technology are already being developed through collaborative efforts with environmental and medical groups. In many of these areas the private sector is working on leap ahead technologies which can be applied to CB Defense problems. Modified versions of a DoD prototype detection system are being used/developed by other government agencies (OGA) and the private sector for use in non-CB Defense capacities.

There is a significant synergy that requires a continuing dialog between defense developers and private industry/academia. CB Defense environments carry with them unique requirements in terms of ruggedness, power and other logistical requirements thus transition of technology from non-CB Defense applications require a significant reengineering effort. Basic research currently being pursued by the national laboratories, OGAs, academia, and the private sector can be used as a foundation to build the future generations of CB Defense detection system.

3.1.3 CB Detection S&T Investment Strategy

3.1.3.1 Technology Demonstrations

Integrated Biodetection ATD. The purpose of this demonstration is to significantly enhance DoD's capability to detect, identify and warn all Services' members on the battlespace against biological agent attacks. Integration of state-of-the-art detection technologies will be linked with communication and warning systems currently not available. A remotely-deployed, early warning biological aerosol detection system will provide local and immediate alert of a biological attack against high value battlefield assets. Enhanced detection and identification technologies with improved sensitivity, selectivity, specificity, and extended range of agents will be demonstrated for application in the Joint Service Biological Point Detection System (J-BPDS). Battlespace simulation and agent simulant outdoor field trials will be used to assess the effectiveness of these technologies.

Air Base/Port Bio Detection ACTD. The Air Base/Port Bio Detection ACTD program will provide extensive biological warfare agent detection, protection, and hazard assessment capability to select Air Ports of Debarkation (APOD) and Sea Ports of Debarkation (SPOD) in foreign allied countries. While the primary focus is on point detection, this program will also demonstrate the necessary individual protection (extended wear mask), collective protection (full or partial systems for selected facilities)

and a capability to collect sensor information and communicate downwind hazard assessments to the next higher level of command. A limited demonstration of the key components and a representative portion of the full system will be demonstrated in CONUS with one port and one airfield fully equipped. This program will support the operation of the system for two years after installation. The intent is to install and operate the full system at foreign APOD/SPOD; CENTCOM and PACOM support this program.

3.1.3.2 Technology Development. The technology development areas for CB Defense are point detection, early warning detection and information processing and dissemination. Point detection encompasses all sampling (in situ) detectors both chemical and biological. In addition the area includes early warning standoff or remote detectors (i.e. sampling detectors on an unmanned aerial vehicle (UAV) or positioned at a distance from the troops with communication via wire or radio link). Early warning detection are technologies that electromagnetically observe clouds at a distance including any non-in situ techniques even if they operate through very short (centimeter) distances. Information processing and dissemination technologies will collect and process all detection system information then disseminate through the C3I network. The detection subarea has been narrowed and focused from over 40 efforts into 9 areas by the recommendations of the Joint Detection Working Group to consolidate the various Service's Science and Technology efforts.

3.1.3.3 Basic Research. The basic research for this subarea is in mass spectroscopy techniques/technologies, optical spectroscopy (includes a wide range of techniques/ technologies), olfactory-like chemical sensing, aerosol sciences, whole cell based biosensors, immuno and DNA assay, molecular approaches to optical sensors, micro-machines, proximal probes and laser development. Basic research relies on work performed by national laboratories, other government agencies, academia, and the private sector in addition to CB defense programs.

3.2. CB Protection

3.2.1 Warfighter Needs

The warfighter needs lighter weight, less burdensome, and more efficient clothing and equipment for respiratory and percutaneous protection as well as improved systems and shelters for collective protection. Improvements in respiratory protective equipment will be demonstrated including a 50% reduction in breathing resistance, 50% increase in field of vision, an increase in protection to guard against potential future threats, improved system integration and compatibility with weapon sighting systems, and 25% improvement in communications capabilities. Respiratory protection technology is scheduled to transition to the Land Warrior program and Dem/Val for RESPO 21. Technologies for lightweight respiratory protection are being considered for potential applications by Special Forces, USMC, and USAF. Joint Service application of RESPO 21 technologies and hardware are planned.

For percutaneous protection, an overgarment based on selectively permeable membrane technology which is 20% lighter in weight than the standard battle dress overgarment will be demonstrated. Further membrane development will lead to an

overgarment which is 20% lighter in weight than the Joint Service Lightweight Integrated Suit Technology (JSLIST) overgarment and also 25% more durable and 25% less costly than the first generation membrane/fabric garment. Ultimately, an agent protective duty uniform which eliminates, or at least minimizes, the need for an overgarment will be developed. Additional efforts involve a stretchable, permeable/adsorptive material with flame retardant properties for lightweight undergarments, socks, and gloves; thermoplastic elastomers for improved overboots and special purpose clothing; improved closure systems for ensembles; microencapsulated phase change materials for special purpose applications, and evolving test methodologies for evaluating new materials. Transition opportunities include Land Warrior, JSLIST II, and advanced development programs. Clothing items resulting from JSLIST II will demonstrate enhancements to JSLIST I items. JSLIST II items will be lighter in weight, less prone to causing heat stress, more durable, launderable up to 10 times, decontaminable for reuse, and wearable for a minimum of 45 days.

Protection must also be provided for individuals and for troops inside vehicles, ships, aircraft and shelters. The collective protection (CP) technology area seeks to develop improvements to existing protective equipment that will allow individuals and groups of personnel to operate in contaminated areas as well as to anticipate future threat CB agents that may be able to compromise current protective equipment. Specifically, air purification systems will allow extended, unencumbered operations in enclosures in an agent contaminated environment and reduce the logistics burden of filter exchange with resultant down-time. Protection against potential filter-defeating chemicals by using regenerative filtration processes will be a major improvement. Regenerative filtration systems are in development for applications such as the Comanche helicopter and armored vehicles. Improvements in materials and engineering to extend usable filter lifetimes are also sought for current single-pass filtration systems used throughout the military.

3.2.2 CB Protection Overview

3.2.2.1 Goals and Timeframes. The goals of the Protection subarea are to maintain a high level of protection against CB agents while reducing the physiological and logistics burden associated with wearing protective equipment; to integrate CB protection with protection from environmental, ballistic, and other threats; and to provide a protective environment for personnel operating in aircraft, armored vehicles, ships, shelters, and other large area enclosures. In FY96/97, applied research efforts will continue to focus on development of a lower bulk/weight general purpose mask to meet Joint Service requirements. New concepts include flexible filter media, advanced lens materials with semi-flexible optical properties, a single piece cylindrical wrap lens design, and an enhanced aerosol filtration system. RESPO 21 technology will transition to demonstration/validation in FY99.

In FY96, a selectively permeable membrane laminated to lightweight textile fabrics will be evaluated in the laboratory and field tested for durability and subjective comfort. The goal is to develop a CB protective overgarment which is 20% lighter in weight than the standard battle dress overgarment. Extensive developmental and operational testing will be conducted during FY97-98. During FY96-98 development efforts will continue to identify alternative selectively permeable membrane candidates.

By FY01, the goal is to develop an overgarment which is 20% lighter in weight than the JSLIST overgarment and also 25% more durable and 25% less costly than the first generation membrane/fabric overgarment. By FY03, the goal is to develop a CB protective duty uniform which eliminates the need for an overgarment.

Technology efforts in collective protection have the objective of developing a fundamental understanding and predictive capability for the purification technologies under investigation. This fundamental understanding will lead to the design of hardware with improved reliability and reduced logistical requirements as compared to current filtration systems. Advanced technology will be used for military platforms currently in development and expected to be fielded within 10 years. Each application (vehicle, aircraft, etc.) requiring collective protection will select an optimum approach (single-pass, Pressure Swing Adsorption (PSA), etc.) early in its development cycle, prior to transition to demonstration/validation (6.4).

3.2.2.2 Major Technical Challenges. Approaches to reduce breathing resistance and improve comfort of respiratory equipment include bonded carbon flexible filters, improved aerosol filtration media, novel low-resistance respiratory valves, and development of improved sealing and blown air systems. To increase protection and meet future threat levels, approaches include development of improved materials for facepieces, lenses and seals. Compatibility with current and future optical and weapon sighting systems will be achieved through flexible lens designs and reduced lens eye relief.

Reduction of heat stress associated with CB protective ensembles will be achieved by developing selectively permeable membranes laminated to lightweight shell fabrics, resulting in thin, lightweight materials with low thermal insulation and high levels of water vapor transport for evaporative cooling. Also, the use of microphase change material will be demonstrated for application on extreme temperature protective clothing.

Collective protection poses numerous technical challenges. Inroads are being made on several fronts including advanced catalysts, engineered adsorbent materials, and improved reactive impregnants. These efforts are based on relationships between filtration performance and physical/chemical parameters in the existing data base. The lack of new concepts or Service requirements for collective protection hinders the development or investment in research for new materials and technologies.

3.2.2.3 Related Federal and Private Sector Efforts. Individual respiratory protection concepts and technology are being considered by 3M Corporation for application in the next generation occupational safety equipment. Battelle is currently marketing electronic devices developed for advanced respiratory protection for commercial applications. Cooperative industrial efforts are being discussed with Geomet Technologies for commercial application of respiratory protection concepts in escape and limited exposure conditions.

W.L. Gore and Associates, Inc. has developed selectively permeable membrane technology which is being thoroughly evaluated for clothing applications. The Department of Energy has an effort for the development of apparel for hazardous waste cleanup personnel which is being leveraged. Continuous coordination and collaborative efforts with the National Institute of Occupational Safety and Health (NIOSH) and the

National Aeronautic and Space Administration (NASA) regarding individual protection technologies is essential.

For collective protection the Project Manager for Aviation Life-Support Equipment (PM-ALSE) is evaluating the possibility of retrofitting a regenerative filtration system based on catalytic oxidation into an existing helicopter. The Project Manager for Comanche is designing a regenerative filtration system based on PSA technology for application in its new helicopter. Private sector efforts incorporating advanced filtration or separation techniques span a wide range of applications from waste stream pollution abatement to gas (air) separation. Regenerative filtration has been used extensively in industry for several decades for gas separation and purification. Application to purification of breathable and separation of trace contamination from high-flow air streams is only now receiving consideration. Other potential applications include environmental remediation, pulsed-power plasma destruction in the electrical power industry, establishing a protected area within a chemical plant in case of accidental chemical spill, odor reduction in vehicle cabin space, development of non-chloro-fluoro-carbon (CFC) conditioning systems, and PSA-based oxygen concentrators (for high performance aircraft applications).

3.2.3 CB Protection S&T Investment Strategy

3.2.3.1 Technology Demonstrations. Individual respiratory and percutaneous protection technology will be demonstrated in a Dismounted Battlespace Battle Lab Warfighting Experiment during FY97. Subsequently, selected technologies will transition to the Land Warrior Program. Respiratory protection technologies will also transition to FY99 demonstration/validation for RESPO 21. A key transition opportunity for clothing materials, in addition to Land Warrior, is the JSLIST II program. Specific improvements targeted by JSLIST II are launderability up to 10 washings without loss in protective capability, decontamination for reuse, lighter in weight and less prone to causing heat stress while having a minimum wear life of 45 days.

3.2.3.2 Technology Development. Applied research efforts in respiratory protection are focusing on prototype development and incorporation of new materials, designs, and manufacturing techniques for lenses, filters, seals, and other mask components. For lightweight CB protective clothing, selectively permeable membranes and membrane/fabric laminates are being developed to meet the goals in this area which include eliminating the dependency on activated carbon. Further work will insure the durability of garments fabricated from these materials as well as their launderability and potential decontaminability for reuse. Additional efforts are being focused on materials and designs for improved closure systems.

The limited resources for collective protection S&T efforts are being focused on improving existing technologies and systems. Technology development is also continuing in the areas of regenerative filtration (PSA modeling), advanced aerosol filtration materials and approaches, and fundamental efforts to correlate adsorbent composition and filtration performance. Examining new collective protection concepts such as using monitors embedded into filter systems to maximize filter life and reduce the overall life cycle cost and logistics support, will require additional funding.

3.2.3.3 Basic Research. Basic research in agent reactive materials is being sponsored by the Army Research Office at Emory University and Oklahoma State

University. These materials have the potential to be incorporated into clothing items to provide self-detoxification in future garments. The Office of Naval Research is sponsoring the development of microencapsulated phase change materials for heating and cooling in response to extreme temperature changes. Participants in this work are the Naval Surface Warfare Center, Navy Clothing and Textile Research Facility, Naval Health Research Center, and the University of Minnesota. Cooling systems for special purpose clothing utilizing these materials have the potential to relieve heat stress. For respiratory and collective protection, fundamental studies of adsorption properties seek to unify several models that describe the adsorption properties of materials based on measured adsorption equilibrium data.

3.3 CB Decontamination

3.3.1 Warfighter Needs

There exists a need for enhanced decontamination systems which are non-corrosive, non-toxic and environmentally safe; suitable for a timely clean-up of CB agents on all materials and surfaces. These materials may be used on personnel, individual equipment, tactical combat vehicles and equipment, sensitive equipment, interior and exterior areas of aircraft, ships, and wide areas such as military bases and shore based naval installations. This requirement includes decontaminants that both remove and neutralize CB agents and procedures to apply these decontaminants as well as techniques that help prevent the spread of CB contamination. These decontamination systems will enable forces to reconstitute personnel and equipment rapidly to increase combat efficiency and lessen the logistic burden.

3.3.2 CB Decontamination Overview

3.3.2.1 Goals and Timeframes. The goal of this subarea is to develop effective, environmentally safe CB decontamination systems to clean-up toxic materials without damaging the contaminated surface or affecting the performance of the equipment being decontaminated. Mid-term requirements are to replace DS2 and develop concepts for aircraft interior decontamination. Long term efforts focus on sensitive equipment and wide area decontamination.

3.3.2.2 Major Technical Challenges. The challenge in this area is finding materials that will meet all the criteria established for a field decontaminant, yet be applicable to the widest range of threat agents. Materials being studied include mild nucleophilic reactants, nucleophilic catalysts, stable oxidants, oxidative catalysts, catalytic enzymes, and organic oxidants. Nucleophilic reagents promote decomposition of G and V agents, while oxidative processes are suitable for H and V agents. The fundamental chemistry of the different chemical classes of agents is a major challenge to overcome. Catalytic enzymes are under investigation are intended to detoxify G, V and H agents. This approach is promising for G and V-agents, but is a technical barrier for H-agents. The requirement that decontaminants be supplied pre-mixed negatively impacts the shelf life of the chemical reagents useful for decontamination.

Another major challenge is finding suitable liquid decontamination media including surfactant systems or environmentally acceptable organic solvent to serve as

the vehicle to carry decontaminants. New decontamination materials need to be stabilized in an appropriate media. In addition, all materials must not interfere with other fielded systems, such as detectors.

Sorbents are an effective way of removing CB contamination from surfaces. However, they do not neutralize the CB contamination removed and thus tend to release absorbed contamination over time. Research into reactive sorbents is an area of potential investigation.

Recent studies have identified interior space decontamination as a critical requirement. This need is especially true in the case of cargo aircraft which may experience interior contamination of critical avionics and other electronic components. The requirement also applies to other interior spaces such as shipboard areas, combat vehicles and buildings.

Decontamination of large areas is not practical during on-going operations. However, post-operational decontamination is desirable. The feasibility and potential methods and technology are currently being examined.

3.3.2.3 Related Federal and Private Sector Efforts. Demilitarization research is being done cooperatively with the U.S. Army Chemical Demilitarization and Remediation Agency in two major programs. In conjunction with the Program Manager for Chemical Demilitarization, alternative methods of destroying the U.S. chemical weapons stockpile are being investigated, in consonance with recommendations from the National Research Council. Also under the office of the Program Manager for Non-Stockpile Chemical Materiel, methodologies for the destruction of non-stockpile chemical items and related environmental remediation are being developed. The Defense Nuclear Agency (DNA) is sponsoring a program to evaluate the effectiveness of a methodology proposed by Russia to destroy their chemical warfare agents stockpile. The DNA also has a related program in the area of Treaty Verification where analytical chemistry sampling and analysis methodology is being developed to perform trace level analysis of chemical agents, agent precursors and degradation products in assorted environmental matrices. The U.S. Environmental Protection Agency, U.S. Army Environmental Center and the private sector are performing research on and are developing technologies for site remediation and restoration. The U.S. is the lead nation for NATO Project Group 31 which is seeking to develop an enzyme-based decontaminant for nerve agents and mustard. The planned decontaminant (based on the U.S. model) is intended for use by all service on equipment, vehicles, facilities and large areas.

3.3.3 CB Decontamination S&T Investment Strategy

3.3.3.1 Technology Demonstrations. The effort to develop Quarternary Ammonium Complexes is scheduled to transition to 6.4 in FY98. Also, the potential exists for the transition of supercritical carbon dioxide technology followed by decontamination treatment of the resulting solutions to serve as a two step procedure to decontaminate sensitive equipment. The 6.3 transition could occur in FY00. Proposed FY97 work on commercial detergents as a DS2 replacement, could lead to an FY00 6.3 transition. Finally, technology utilizing fire suppressant and other foams to deliver catalytic enzymes and other materials to effect multi-agent decontamination will be demonstrated against a broad spectrum of agents in FY06.

3.3.3.2 Technology Development. There is limited funding for Decontamination S&T efforts such that the commodity area is essentially at a technology watch status. Available resources are focused on decontaminants, operational materials, and contamination control.

Biochemical investigations in this area are directed toward finding reactive enzymes which will be effective against all CB threat agents. These must be stable in storage and environmentally acceptable. Various approaches are being taken to optimize the use of enzymes. Studies continue into the use of enzymes incorporated into various foam systems. This would allow for the use of fielded fire fighters' equipment for surface application. Tests will also be conducted using new formulations of quaternary ammonium complexes against CW agents with emphasis on devising ways to control viscosity and develop means to optimize efficiency and effectiveness.

There exists a requirement to replace DS2 with a significantly less corrosive and more environmentally acceptable material. For this purpose, a study is planned to be initiated in FY97 using commercially available oxidizing detergents. Also, in a recent Decontamination Workshop, new technology for future investigation was identified. The most promising approach is the use of supercritical carbon dioxide technology. This approach would require a two step procedure, using the supercritical carbon dioxide to remove the agent from surfaces, such as sensitive equipment, and following that with destruction of the collected contaminant. Investigations are planned for FY97.

Preventing the spread of contamination or preventing combat equipment from becoming contaminated greatly eases the later decontamination process and permits equipment to be used much more quickly after a CB attack. This technology effort is investigating procedures and materials that will prevent contamination from spreading to the interiors of combat equipment and aircraft or aid in rapid clean-up of contamination to reduce the spread of contamination. Work to date has concentrated on aircraft interiors. In addition, by the end of FY97, a plan will be completed to assess the feasibility of large area decontamination and, if deemed worthy of further investigation, a road map and funding plan will be detailed.

3.3.3.3 Basic Research. The chemistry at organized interfaces in solutions (micelles, emulsions, microemulsions, vesicles, liposomes) has proved to be extremely useful for enhanced reactivity needed for decontamination technology advances. Recently, novel types of polymeric support termed "starburst" dendrimer polymers have been developed. The ability to attach substances that can serve as catalysts to the surface of dendrimers has been shown. Studies are planned to examine the use of such systems to decontaminate CB agents in environmental matrices.

3.4 CB Studies, Analysis And Simulation

3.4.1 Warfighter Needs

The models generated or enhanced under this subarea will allow CB warfare effects to be assessed either separately or in conjunction with other meteorological and terrain effects in a variety of hazard assessment systems. The primary Warfighter need is to develop a simulation capability which integrates all available sensor data (CB detectors along with other relevant information such as meteorological and geographical data) and

provides Commanders with a decision aid to determine the appropriate protective posture, actions to avoid contamination, and means to predict areas of contamination. Such CB effects models under development include:

CB Defense Integrated Meteorological and Contamination Transport (CBD-IMPACT). This is a planned upgrade to the Maneuver Control System (MCS) for FY97 to allow operational computating of mesoscale meteorology and subsequent CB hazards on the MCS workstation.

Hazard Prediction Systems Integration Program (HPSIP). HPSIP is being developed for quantifying and visualizing areas affected by and casualties caused by NBC weapons to assess technological and natural hazards associated with operations other than war. The system will be hosted on a Unix open system workstation with the ability to operate on a laptop computer for field deployments. Weather data digest, population data bases and a Geographic Information System (GIS) will be included.

Hazard Prediction Assessment Capability (HPAC). HPAC is a series of models that address source term generation, transport and diffusion, and 3 dimensional modeling of meteorological conditions with interaction of complex terrain. These models are integrated into a single automated package design to run on a workstation. The program will assess the impact of an accidental release of hazardous materials during military operations.

Post Engagement Ground Effects Model (PEGEM). This is one of several systems under development by the Ballistic Missile Defense Organization (BMDO) to compute the effects of intercepting a missile with a nuclear, conventional, chemical or biological warhead. A version of VLSTRACK is being modified to meet the requirements of high altitude transport and diffusion.

3.4.2 CB Studies, Analysis and Simulation Overview

3.4.2.1 Goals and Timeframes. The overall goal of the Studies, Analysis and Simulation subarea is to provide systems which will provide situational awareness and aid command evaluations, integrate sensor data, and permit realistic training and simulation of the CB battlefield environment. A current thrust is to take advantage of the rapidly increasing computational power in personal computers/workstations by incorporating terrain, geolocation information, mesoscale meteorology and objects such as tanks, ships or buildings into CB warfare effects models. Steps are also being taken to add a realistic CB warfare capability to models such as JANUS and in wargames. The development of hazard assessment models for use by operational forces is another major focus.

CB warfare models are being continuously improved to provide a more realistic depiction of the hazard. Development and integration into various systems is coordinated with other system improvements to ensure that the maximum synergism is obtained. For example, the fidelity of the CB warfare model must be matched with the fidelity of the meteorological data which is available as an input. The first model to be fielded operationally was PC-based and used single hourly meteorological inputs. The next implementations were operational in FY95 and utilized 3-D meteorological grids which are computed at centralized CONUS sites and transmitted to the command centers in the theater of operations. The first accredited, Joint Service CB warfare hazard model will be

adopted by FY96. By FY98, regional meteorology will be calculated in theater and used by the operational CB warfare models. As more sophisticated methodologies such as Navier-Stokes methods are validated, they may replace current methodologies by the FY97/98 timeframe.

Critical decisions that will be made from an operational hazard assessment require rigorous verification, validation and accreditation of models. Likewise, when these models are used for acquisition decisions such as selection of the best ballistic missile interceptor, or the optimal method of early warning of biological threats, it is vitally important that models be based on sound physics and validated with an appropriate set of field trials. In FY95, a semi-automated CB warfare model validation capability was developed. The effort will incorporate over 3000 data points from both classified and unclassified field trial reports.

3.4.2.2 Major Technical Challenges. The primary technical challenges in this subarea are data gathering from numerous sensors and sources, data generation for validation of the models, manipulation of large data bases for real-time simulations to reduce computer running time, and providing a simplified output and decision aides for easier interpretation of results. Other technical challenges include evaluation of a 3-dimensional Navier-Stokes flow code for more realistic profiles, developing high resolution models for the Distributed Interactive Simulations (DIS), and establishing threat/toxicity/exposure levels for CB agents with the models under various scenarios.

The lack of a standard CB warfare hazard assessment model for the Services has been a problem in the past. This is being overcome by the adoption of the Vapor, Liquid and Solid Tracking (VLSTRACK) model by the Joint Services for nearly all atmospheric CB agent releases. Benefits of VLSTRACK have been established by the Ballistic Missile Defense Organization's International Model Comparison Working Group. This standardization means that identical model operation and output can be expected in studies, training, simulation and operational situations. It has also greatly reduced duplication.

In the area of hazard analysis, study of BW agent detection requirements and medical prophylaxis is receiving added attention. During Operation Desert Storm, the U.S. and its allies had to hastily assemble the capability to analyze the potential BW hazard and how to counter it. There are a number of data gaps (such as toxicity) which are virtually impossible to fill, and others (such as determining the representative size distribution of various releases) which are readily achievable. Even now, automated methods to accurately and realistically analyze the effectiveness of existing or planned BW detection/identification systems are not available. Existing models and databases are unsuitable for accurately estimating total airborne concentrations of particles (combination of agent and background aerosol) as a function of size. New algorithms are under development for simulating both point and standoff detectors.

The major reasons for improving the CB warfare methodology in existing combat simulations is to make the simulation more realistic and to facilitate the use of CB warfare effects in wargames or assess the impact of CB warfare on an already well understood process, such as Sortie Generation. This requires the use of relatively rigorous CB warfare models. However, most simulations lack the computer power to incorporate complex methodology without unacceptably lengthening their run time. It is possible that two different versions will be needed to satisfy the needs of both the

scientific/engineering and training communities. No data exists for impact on operations from integrated wings or airlift missions. The Measures of Effectiveness for these operations are much more complex than sortie generation which serve well for air-to-air and air-to-ground missions.

The lack of easy to use and credible simulation of CB agent effects has greatly impeded the ability to perform meaningful CB warfare in operational simulations. The ability to incorporate CB warfare effects into both the constructive and virtual processes of DIS represents a significant technical challenge due to the high fidelity, engineering level, cloud transport and diffusion model required and pervasive degree to which the CB environment is to be put all through the synthetic battlefield. In order to provide this capability in time to meet urgent materiel development schedules, a broad based strategy is being followed which includes several simultaneous technology efforts. These involve adaptation of VLSTRACK as a standard transport and diffusion model, point and standoff CB agent detectors, and man-in-the-loop simulators of CB unique vehicles such as the M93A1 Nuclear, Biological and Chemical Reconnaissance System (NBCRS or FOX vehicle) and the Biological Integrated Detection System (BIDS).

In addition to model development itself, there is a requirement to collect ground truth data to evaluate model performance. Exercises such as the annual Joint Field Trials at Dugway Proving Ground, as well as a follow-on to other data collections such as the Joint Contact Point over-the-water line source dissemination data collection effort, will provide a valuable basis for critical and now lacking data for evaluation of model performance.

3.4.2.3 Related Federal and Private Sector Efforts. Studies, analysis and simulation programs support various elements of The Technical Cooperation Program (TTCP), including TP9 - CB Hazard Assessment, the MOU with US/UK/CA including ITF25 - Threat from Industrial Chemicals, and the NATO Ad Hoc Working Group 111 - Modeling and Simulation, and WGE.1 - CB Warfare Hazard Assessment. The Ad Hoc Working Group 111 is studying DIS to resolve command and control, interoperability and other multi-national mission issues (including CB warfare effects).

3.4.3 CB Studies, Analysis And Simulation S&T Investment Strategy

Following the 1994 Technology Area Review of CB Defense Science and Technology Base Programs, a CB Modeling Process Action Team (PAT) was established. The objectives of the PAT are (1) to recommend a coordination and integration process for CB models and simulations, (2) to recommend CB modeling and simulation requirements generation process, (3) to identify and prioritize modeling and simulation requirements, (4) to recommend means to reduce duplications of efforts, and (5) to provide a forum for communicating concerns and issues. From the operations and technical development perspective, the goal of the PAT is to provide a means to use the same performance measurements for any given technology effort or wargame.

3.4.3.1 Technology Development. Providing realistic agent challenge levels for all situations requires continuous improvement in modeling methodologies and algorithms to cover the increasing variety of applications, such as modeling the behavior of CB agents released at high altitudes following the intercept of a CB warhead. Likewise, making hazard models available to and their output suitable for use by the

battlefield commander as a decision aid also requires considerable modification to models previously used primarily for research and engineering

3.4.3.2 Basic Research. There is no basic research funding for simulation. However, data from related basic research efforts, such as aerosol sciences, provides critical information for updating data for models and simulations.

3.5 Warfighter Support (Nuclear)

Technical activities and technology development that respond directly to warfighter requirements by ensuring confidence in the effectiveness, security, and safety of nuclear capabilities; and developing and demonstrating the planning tools and other resources needed to support operations in contingencies involving proliferants.

3.5.1 Warfighter Needs

Weapons that are effective and appropriate for proliferation scenarios are needed. Particular emphasis is given to improving capabilities for defeat of hardened targets (especially those associated with WMD) with minimized collateral hazards. This RDT&E applies both to the post-cold-war nuclear mission and to the tasking from the Secretary of Defense to apply nuclear research expertise to improve understanding of advanced conventional munitions and weapon-target interactions.

3.5.2 Warfighter Support Overview

3.5.2.1 Goals and Timeframes. By FY96, establish DoD dual revalidation teams at DOE nuclear weapon labs and IOC for DNA M&S center. By FY96, complete nuclear weapon safety assessment for strategic aircraft. By FY98, transition new physical security applications for nuclear systems to Army and Air Force; transfer new planning systems for contingency scenarios to NATO; demonstrate and assess options for functional defeat of hardened NBC and C3I facilities; and complete WMD theater-level engagement model. By FY99, demonstrate improved capability for forecasting hazards that might result from attack of a facility containing WMD. By FY00, complete 21st Century nuclear survivability plan and provide WMD models for JWARS/ JSIMS. By FY05, complete dual-revalidation of nuclear weapons stockpile.

3.5.2.2 Major Technical Challenges. Long-term stockpile stewardship using only non-nuclear laboratory technologies plus modeling and simulation and probabilistic risk assessment is without precedent. Stockpile stewardship involves more than a physics package. DoD must address end-to-end operation of critical delivery and C3I systems. Planning capabilities must be adapted to proliferant contingencies including, as one example, the attack of a WMD target with conventional weapons in which collateral hazards result from the target. Full-physics effects models must be translated into operational planning/visualization tools.

3.5.2.3 Related Federal and Private Sector Efforts. DOE stockpile revalidation and other Science-Based Stockpile Stewardship activities are critical for accomplishing DoD nuclear missions. DoD dual-revalidation teams are being assigned to participate in these activities, commencing in FY96. Research demonstrating safety

methodologies and providing better methods for predicting and mitigating collateral hazards has potential for technology transfer to the civil sector.

3.5.3 Warfighter Support S&T Investment Strategy

3.5.3.1 Technology Development. All of the activities in this subarea involve technology development; there are no basic research or ATD/ACTD technology demonstrations.

Stockpile Support: Initial dual-revalidation objectives have been defined. Safety research uses probabilistic risk assessment methodologies adapted to multiple-failure-point analysis; there is close collaboration with USAF customers for this work. Physical security R&D for nuclear systems is coordinated by OSD.

Planning Systems for Contingencies Involving Proliferants: Priorities are defined by U.S. CINC and SHAPE users. Target planning capabilities are being adapted to respond to proliferation contingency requirements. Survivability programs focus on the new, Nuclear Posture Review, stockpile. A direct technical support capability has been established to provide support to theater operations, as done during DESERT STORM for WMD hazard prediction and target analysis.

Improving Weapons' Effectiveness: Particular emphasis is given to evaluating options for defeat or functional disruption of buried and other hardened targets.

Collateral Hazards: Forecasting methodologies are being adapted to address WMD effects dispersion in situations in which local environmental factors dominate. A currently unfunded Army program would reduce radiation doses to military personnel.

3.6 Systems Effects & Survivability (Nuclear)

3.6.1 Warfighter Needs

The warfighter needs radiation and electromagnetic hardened systems and microelectronic pieceparts in order to survive the threat and perform his mission. DoD has unique needs for radiation hardened microelectronics that can survive radiation fluence levels that commercial-off-the shelf microelectronics cannot satisfy. Additionally, the availability of nuclear weapons technology and sophisticated delivery sytems has led to the emergence of a new threat—the high altitude detonation of one or two low-yield weapons. Proliferation makes the likelihood of employment in a regional conflict ever more likely and this threat places unprotected space and ground systems at risk.

This subarea has two technical thrusts: the development of affordable state-of-the-art radiation hardened microelectronics and the integrated hardening and testing of military systems against high altitude electromagnetic pulse (HEMP) and high power microwave effects. The bottom line objective is to ensure that warfighters have confidence in the survivability of their weapons systems in all radiation environments.

3.6.2 Systems Effects & Survivability Overview

3.6.2.1 Goals and Timeframes.

FY96	- Decision on scope and funding of balanced electromagnetic hardening technology program and other integrated protection initiatives - Complete National Defense Infrastructure Survivability Study - Begin development of enabling technology for a radiation hardened 4 M SRAM demonstration circuit - Develop radiation hardened design and test requirements for AGT testable systems
FY97	- Develop initial design and test protocols for radiation hardened systems (testable by AGT) - Complete end-to-end C4I link survivability assessment
FY98	- Adapt protection practices for EM shielding with composites and other nonmetallic materials - Demonstrate, test, and evaluate radiation hardened silicon-on-insulator analog microelectronics technology
FY99	- Refine methodologies for design and test protocols for radiation hardened systems (testable by AGT) - Develop initial recommendations on improved shielding effectiveness testing system covering both EMP and HPM frequency ranges
FY00	- Demonstrate enabling technology for radiation hardened low-power 1000k gate array and 16M SRAM - Produce, test and evaluate radiation hardened cryogenic analog microelectronics - Validate design and test protocols for radiation hardened systems (testable by AGT) - Develop updated hardness maintenance/surveillance techniques and standards in accordance with newly-developed hardening technology
FY01	- Produce affordable technology and methodology for integrated hardening and testing of military systems against HPM and HEMP effects (assuming favorable FY (funding decision) - Deliver design and test protocols for radiation hardened systems (testable by AGT)

3.6.2.2 Major Technical Challenges. Military systems continuously require increased information processing but state-of-the-art commercial semiconductor processes are designed primarily to maximize profits, usually at the expense of such desirable characteristics as radiation hardness. Thus, succeeding generations of microelectronics have become increasingly susceptible to radiation. DoD must therefore maintain an ongoing effort to radiation harden new generations of microelectronics as they evolve to ensure that future warfighters have the survivable state-of-the-art electronics systems needed to complete their missions. Additionally, the loss of UGT capability requires the development of new design and test protocols and procedures that

assure system survivability. Validation activities are necessarily dependent on test and simulation capabilities, which are addressed in the next subarea.

3.6.2.3 Related Federal and Private Sector Efforts. Radiation hardened electronics are critical for the multi-billion-dollar commercial and civilian space industry. Balanced hardening methodologies have considerable potential for transfer to the private sector. Notable is the proposed use of European Union protection standards that are more stringent then their US commercial equivalents. Computational structural dynamics methodologies for enhancing the survivability of military facilities have direct applicability for providing civilian structures with protection against both natural, e.g., earthquake, and man-made, e.g., terrorist, hazards.

3.6.3 Systems Effects and Survivability S&T Investment Strategy

3.6.3.1 Technology Development. All of the activities in this subarea involve technology development; there are no basic research or ATD/ACTD technology demonstrations.

Radiation Effects: The major objective, which is a DDR&E directed priority, is development of radiation hardened electronics enabling technology for missiles and space systems that could be exposed to proliferant nuclear weapons effects. A second objective is to ensure that the communications and sensors of these space assets are not disrupted by the disturbed environment caused by such a high-altitude event. Finally, the third objective is to ensure the ground terminals associated with these assets are protected from the HEMP that such an event can produce. Toward these ends, the threats posed by a proliferant's weapons are being better characterized and methods for protecting and testing that protection are being developed.

Balanced Hardening: The objective in this (not fully funded) program is to develop and demonstrate integrated hardening technology and methodologies. These methodologies would reduce costs by allowing a smaller number of validated tests to be conducted to verify protection against multiple hazards. Technology development would involve new lower cost approaches for integrated effects testing and protection validation. This approach is congruent with new DoD acquisition policies mandating much greater use of commercial parts and standards. Priority would be given to protection against High Power Microwave and High Altitude Electromagnetic Pulse effects with consideration given to the whole spectrum of electromagnetic interferences and disturbances. The goal is to achieve the optimum electromagnetic protection for systems balancing the competing factors of threat, cost, size/weight, and technical/engineering feasibility.

3.7 Test and Simulation Technology (Nuclear)

3.7.1 Warfighter Needs

These technology development efforts respond to Presidential Decision Direction 15 and other national and department direction by providing the capabilities needed to validate military system performance in nuclear and related weapon environments. In the absence of underground tests and without the ability to simulate nuclear weapons effects,

there can be little confidence in military systems being able to operate in such environments. Stockpile stewardship requires test and simulation technology to ensure end-to-end confidence in critical delivery and C3I systems.

3.7.2 Test and Simulation Technology Overview

3.7.2.1 Goals and Timeframes. By FY96, have an IOC for the Large Blast/Thermal Simulator (LB/TS); and complete the DECADE technology assessment. By FY97, provide non-ideal simulation capability at LB/TS; and complete simulator close-outs at the Army Research Lab (Aurora simulator) and Maxwell Laboratory (Blackjack 5, Blackjack 3/3, and Modular Brehmstralung simulators) facilities. By FY98, have IOC for the first quadrant of the DECADE radiation simulator (assuming favorable FY96 decision); and have a decision on a plasma radiation source approach or an alternative simulator. BY FY99, complete performance verification for debris shield in radiation simulators. By FY00, complete the simulator consolidation. By FY01, assess the viability of DOE X-ray sources for nuclear weapons effects simulation.

3.7.2.2 Major Technical Challenges. Given termination of underground nuclear tests, there are significant shortfalls in simulator fidelity and with respect to the size of objects that can be tested. Due to funding constraints, investment in new, potentially more cost-effective, simulation technologies has been curtailed. Effort focuses on consolidation of existing facilities, completion of ongoing development efforts, and incremental improvements to in-place capabilities.

In Blast/Thermal simulation, a near-term priority is to respond to Army requirements by adapting LB/TS to simulate non-ideal airblast effects. Once this is done, the limits of existing technology will have been reached. Unmet requirements include improved high-temperature, high-flux thermal sources; and the ability to simulate a wider range of blast phenomenologies.

For radiation simulation, there are major shortfalls in capabilities for testing full-size systems or subsystems against all types of X-rays. With the UGT moratorium, the ability to test the response of materials, optics, and structures to the cool portion (under 40 KeV) of the X-ray threat has been severely curtailed. Plasma radiation sources implemented on existing simulators are attempting to fill this gap. At present, available debris-free fluence-areas are approximately 5 cal. Investigation of innovative and efficient cold X-ray sources with ten times larger debris-free fluences and better fidelity continues. DECADE will provide the capability to test the response of small systems to hot X-rays (>40 keV). DECADE will probably be constructed in phases. The first phase ("DECADE Quad") will provide a 20,000 Rad Dose over 2500 cm^2, providing a 400% increase in performance over current hot X-ray simulators. Improvements are needed in cold X-ray plasma radiation source fidelity and stability, debris shields to provide high-fidelity test environments for plasma sources, the reliability and repeatability of plasma switches used in radiation simulators, synchronous use of modular pulsed power devices, and diagnostics that can function in the harsh environments produced by X-ray simulators.

UGT readiness is being accomplished through the combination of a bare-bones investment in test site infrastructure and development of a detailed model showing what must be done to reconstitute a test capability if this is directed by national authorities at some point in the future.

3.7.2.3 Related Federal and Private Sector Efforts. Planning gives explicit consideration to options for use of DOE simulators to respond to DoD requirements. DOE plans and development efforts that, if successful, might respond to DoD needs are being monitored, e.g., the National Ignition Facility and Science-Based Stockpile Stewardship programs. Significant opportunities for technology transfer to the private sector are associated with some of the technologies in this subarea, including high energy density capacitors (medical, radar, and commercial power system applications), flash X-ray technology (food processing sterilization), and X-ray modeling and source development (higher resolution, lower exposure, diagnostics).

3.7.3 Test and Simulation Technology S&T Investment Strategy

3.7.3.1 Technology Development. All of the activities in this subarea involve technology development; there are no basic research or ATD/ACTD technology demonstrations.

Blast/Thermal Simulation: LB/TS provides a new, repeatable, capability. Programmed enhancements for non-ideal airblast simulation respond to Army requirements.

Radiation Simulation: A near-term decision is anticipated for the initial quadrant of the DECADE radiation simulator. With major inputs from a Reliance task force, the DoD nuclear effects simulator suite is being consolidated. This includes transfer and reuse of debris mitigation schemes, cryogenics, and other capabilities to the simulation facilities that are to be retained. New switching technologies for pulsed power sources will be evaluated.

UGT Readiness: A minimal capability is being retained at the Nevada Test Site. Effort is underway on documentation and on development of a model providing the information needed for test activity reconstitution.

3.8 Scientific and Operational Computing (Nuclear)

3.8.1 Warfighter Needs

Application and preservation are major themes in these activities which respond to warfighter requirements for survivable systems and effective nuclear weapons. Preservation, because the Defense Department’s understanding of nuclear weapon effects is based in large part on test data that is unique and, in many instances, perishable. Applications involve the packaging of U.S. nuclear data and physics understanding into advanced computational products that enable fundamentally new capabilities for warfighter interaction and visualization. In addition, there are aspects of our understanding of nuclear matters that require utilization of advanced computational resources, e.g., for investigation of the physics involved in weapon-target interactions, and for extrapolating from test results in circumstances in which new tests are not possible.

3.8.2 Scientific and Operational Computing Overview

3.8.2.1 Goals and Timeframes. By FY96, distribute computational aid providing an integrated methodology for calculating all nuclear weapon effects and Transient Radiation Effects on Electronics (TREE) Handbook. By FY97, provide users with on-line access to information and services at DASIAC (DoD repository for nuclear effects information). Complete bomb-in-structure modeling. Complete colleteral effects cloud transport model. By FY98, complete distribution of EM-1, primary engineering handbook for nuclear weapons effects; and transition computational support to a combination of the DoD High Performance Computing architecture and departmental hardware. Complete electro-thermal chemical gun model. By FY99, complete incorporation of underground nuclear test data into DARE (Data Archival and Retrieval Enhancement) system. By FY00, complete entry of nuclear simulator data into the DARE system. By FY01, complete incorporation of nuclear testing data and provide users with on-line access to DARE resources.

3.8.2.2 Major Technical Challenges. The nuclear effects computations program develops tools for accurate prediction of the evolution of turbulent fields embedded in explosions. Past work emphasized nuclear effects topics. Current focuses, which give particular emphasis to counterproliferation-relevant research, include turbulent combustion and afterburning induced by explosions in chamber systems (needed for engineering control over chemical explosions), formation of hazardous combustion clouds (to minimize collateral hazards associated with such events), turbulent combustion in guns (to produce range enhancement via controlled energy release), and turbulent mixing in bomb implosions (a topic to be addressed in stockpile revalidation, e.g., the DOE Advanced Scientific Computing Initiative). All of these applications are in line with direction from OSD to make use of nuclear technical expertise in designated non-nuclear applications.

It is generally recognized that turbulent mixing is the central unresolved physics problem for virtually all fluid-dynamic phenomena associated with explosions. A six-step approach has been demonstrated as providing reliable prediction of the evolution of turbulent explosion fields. This involves (1) convective mixing simulations of 3-D turbulent fields, (2) use of Adaptive Mesh Refinement to capture enough of the turbulence spectrum to reach the inertial range; (3) sub-grid modeling of molecular processes; (4) averaging of 3-D solutions to extract fields for engineering analysis; (5) corroboration of convective mix approximations by performing 3-D Navier-Stokes calculations of turbulent flows for limited spatial domains; (6) verification of numerical results by comparison with well-controlled laboratory experiments. A variety of state-of-the-art computational methods are used for the compressible and incompressible flow cases.

The nuclear testing database is unique and irreplaceable. Critical information is on perishable media, e.g., films and photography from the 1950s atmospheric test series. Data quality assurance is imperative. This is the last opportunity to involve experimenters who were participants in the atmospheric and underground nuclear test programs in the review of this data; their insights concerning the merits and limitations of this database must be captured and preserved. For computational aid products, user groups are employed throughout the development process to ensure products respond to customer requirements.

3.8.2.3 Related Federal and Private Sector Efforts. The Department of Energy organizations responsible for science-based stockpile stewardship plan to use the DOE Accelerated Strategic Computing Initiative as a primary mechanism for sustaining nuclear competence. Appropriate levels of DoD customer involvement, e.g., in dual-revalidation, are required.

3.8.3 Scientific and Operational Computing S&T Investment Strategy

3.8.3.1. Technology Development. All of the activities in this subarea involve technology development; there are no basic research or ATD/ACTD technology demonstrations.

DASIAC/DARE: DASIAC is the DoD Nuclear Information Analysis Center, chartered to preserve DoD nuclear-weapons-related information. DARE (Data Archival & Retrieval Enhancement) is a new program that uses optical media for long-term data preservation.

Computational Aids: This program develops the authoritative products used throughout the U.S. Government and allied nations for nuclear effects data and calculations, including EM-1, the primary technical reference for nuclear weapons effects, and a variety of engineering-oriented computational products.

Nuclear Effects Computations: This program provides computational support for nuclear analyses and operations; an example of the latter was direct technical support to the theater for hazard forecasting during the Gulf War.

4. TECHNOLOGY AREA ROADMAPS AND RESOURCES

4.1 Technology Area Roadmap - See Figure II.3.

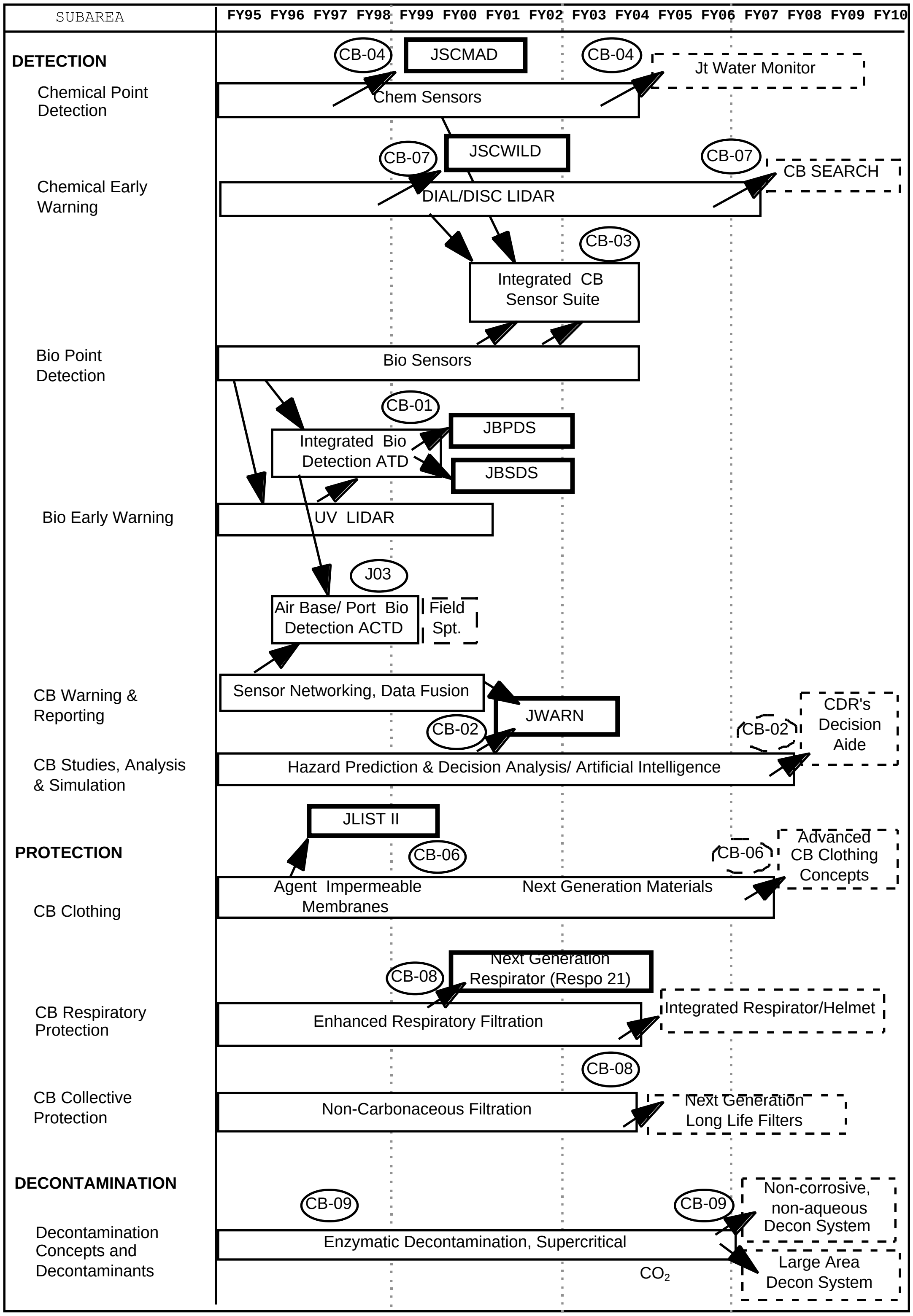


Figure II.3. CB Defense and Nuclear Technology Roadmap

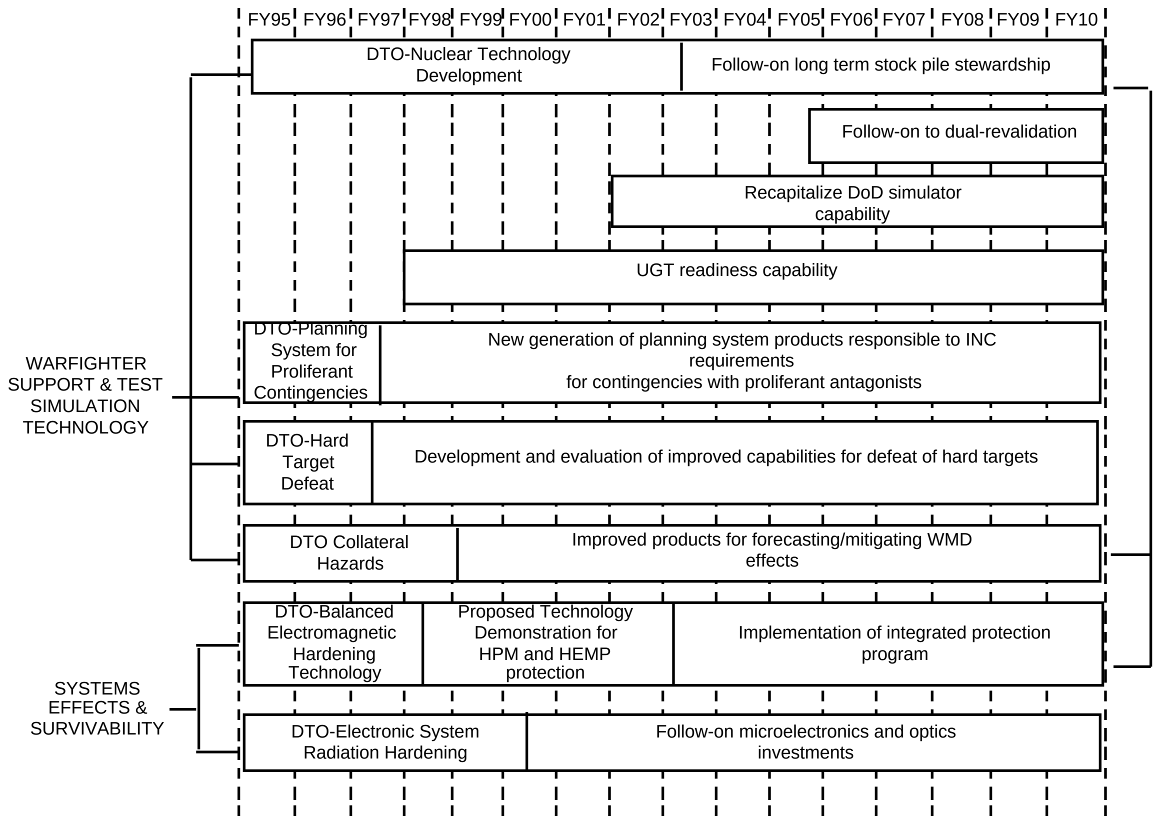


Figure II.3. Nuclear Technology Roadmap (cont.)

4.2 Chemical, Biological Defense, and Nuclear Technology Roadmap Resources (M)

DTOs	Program Element	$ in millions					
		FY96	FY97	FY98	FY99	FY00	FY01
CB-01-10-D Integrated Biodetection ATD	0602384BP	9.1	8. 8	8.7	0	0	0
	0603384BP	4.0	5.8	6.8	5.8	0	0
	DTO Total	13.1	14.6	15.5	5.8	0	0
CB-02-10-D JWARN	0602384BP	--	0.3	0.7	0.7	2.1	2.2
	DTO Total	--	0.3	0.7	0.7	2.1	2.2
CB-03-10-D Integrated CB Sensor Suite	0602384BP	--	0. 9	1.3	1.3	2.6	2.7
	DTO Total	--	0. 9	1.3	1.3	2.6	2.7
CB-04-10-D JSCMAD	0602384BP	1.8	1.4	1.4	0. 5	0	0
	0603384BP	- -	--	1.7	3.5	0	0
	DTO Total	1.8	1.4	3.1	4.0	0	0
CB-05-10-D Airbase/Port Bio-Detection ACTD	0603750D	2.0	3.0	1.0	2.0	1.0	0
	0604384BP	1.0	2.0	17.0	0	1.0	0
	0604384CP5	1.0	2.0	1.0	0	0	0
	DTO Total	4.0	7.0	19.0	2.0	2.0	0
CB-06-12-D Advanced Ltwt Chem Protection	0602384BP	0.8	0.9	1.2	0.6	0.5	0
	DTO Total	0.8	0.9	1.2	0.6	0.5	0
CB-07-10-D Laser Standoff Chem Detection	0602384BP	1.3	0.5	0.8	0.8	2.2	2.1
	0603384BP	--	--	--	--	6.5	5.8
	DTO Total	1.3	0.5	0.8	0.8	8.7	7.9
CB-08-12-D Advanced Agent Filtration	0602384BP	3.1	3.1	3.0	3.1	4.1	4.5
	DTO Total	3.1	3.1	3.0	3.1	4.1	4.5
CB-09-12-D Decontamination for Global Reach	0602384BP	0.2	0.8	0.8	0.8	0.8	0.8
	0603384BP	- -	- -	- -	- -	2.8	3.8
	DTO Total	0.2	0.8	0.8	0.8	3.6	4.6
CB-10-07-H Nuclear Technology Development	0602715H	53.9	50.2	55.9	52.9	49.9	48.2
	DTO Total	53.9	50.2	55.9	52.9	49.9	48.2
CB-11-07-H Planning Systems	0602715H	8.9	11.7	13.7	15.8	16.0	16.8
	DTO Total	8.9	11.7	13.7	15.8	16.0	16.8
CB-12-01-H Electronic System Radiation Hardening	0602715H	24.3	20.7	22.0	21.9	25.1	27.2
	DTO Total	24.3	20.7	22.0	21.9	25.1	27.2
CB-13-07-H Hard Target Defeat	0602715H	7.9	5.6	10.5	12.2	13.7	14.4
	DTO Total	7.9	5.6	10.5	12.2	13.7	14.4
CB-14-07-H Collateral Hazards	0602715H	4.4	5.2	5.8	5.8	6.0	5.5
	DTO Total	4.4	5.2	5.8	5.8	6.0	5.5
CB-15-01-H Balanced EM Hardening Tech	0602715H	5.0	2.7	2.7	2.9	2.8	2.9
	DTO Total	5.0	2.7	2.7	2.9	2.8	2.9

Figure II.4. Chemical, Biological Defense, and Nuclear Technology Roadmap Resources

TOTALS MAY NOT AGREE DUE TO ROUNDING

CHEMICAL, BIOLOGICAL DEFENSE, AND NUCLEAR ACRONYMS

AGT	Above Ground Testing
APOD	Air Ports of Debarkation
ASCI	Accelerated Strategic Computing Initiative
ACTD	Advanced Concept Technology Demonstration
ATD	Advanced Technology Demonstration
BIDS	Biological Integrated Detection System
BMDO	Ballistic Missile Defense Organization
BW	Biological Warfare
C3I	Command, Control, Communications and Intelligence
C4I	Command, Control, Communications, Computers and Intelligence
J-BREWS	Joint Biological Remote Early Warning System
CB	Chemical-Biological
CBD-IMPACT	CB Defense-Integrated Meteorological and Contamination Transport
CENTCOM	Central Command
CINCs	Commanders in Chief
CONUS	Continental United States
CP	Collective Protection
CW	Chemical Warfare
DARE	Data Archival and Retrieval Enhancement
DASIAC	Defense Atomic Support Information and Analysis Center
DBBL	Dismounted Battlespace Battlefield Laboratory
DIS	Distributed Interactive Simulations
DNA	Defense Nuclear Agency
DNA	Deoxyribonucleic Acid
DOE	Department of Energy
EM	Electromagnetic
ERDEC	Edgewood Research, Development and Engineering Center
EMP	Electromagnetic Pulse
GEN II	Generation II Soldier
GIS	Geographic Information System
HAZWARN	Hazard Warning System
HEMP	High Altitude Electromagnetic Pulse
HPAC	Hazard Prediction Assessment Capability
HPC	High Performance Computers
HPM	High Power Microwave
HPSIP	Hazard Prediction Systems Integration Program
IOC	Initial Operational Capability
IR/UV	Infrared/Ultraviolet
J-BPDS	Joint Service Biological Point Detection System
J-BREWS	Joint Biological Remote Early Warning System
J-BSDS	Joint Service Biological Standoff Detection System
JSCMAD	Joint Service Chemical Miniature Agent Detector
JSCWILD	Joint Service Warning and Identification LIDAR Detector
JSIG	Joint Service Integration Group
JWARS/JSIMS	Joint Warfare Simulation/Joint Simulation System
JSLIST	Joint Service Lightweight Integrated Suit Technology
JSMG	Joint Service Materiel Group
JSNBCRS	Joint Service Nuclear, Biological and Chemical Reconnaissance System
JWARN	Joint Warning and Reporting Network

JWSTP	Joint Warfighting Science and Technology Plan
LB/TS	Large Blast/Thermal Simulator
LIDAR	Laser Imaging Detection and Ranging
MICAD	Multipurpose Integrated Chemical Agent Alarm
Micro PCMs	Microencapsulated Phase Change Materials
NASA	National Aeronautic and Space Administration
NATO	North Atlantic Treaty Organization
NBC	Nuclear, Biological and Chemical
NIOSH	National Institute of Occupational Safety and Health
NRDEC	Natick Research, Development and Engineering Center
OCONUS	Outside Continential United States
PACOM	Pacific Command
PAT	Process Action Team
PEGEM	Post Engagement Ground Effects Model
PM-ALSE	Program Manager-Aviation Life Support Equipment
PSA	Pressure Swing Adsorption (filtration technology)
RDT&E	Research, Development, Test and Evaluation
RESPO 21	Respiratory Protection System 21
SHAPE	Supreme Headquarters, Allied Powers Europe
SOI	Silicon on Insulation
SPOD	Sea Ports of Debarkation
SRAM	Static Random Access Memory
STB	Super Tropical Bleach
TPCBD	Technology Panel for Chemical, Biological Defense
TREE	Transient Radiation Effects on Electronics
TTCP	The Technical Cooperation Program
UAV	Unmanned aerial vehicle
UGT	Underground Testing
VLSTRACK	Vapor, Liquid and Solid Tracking
WMD	Weapons of Mass Destruction

III. FY 1997 DEFENSE TECHNOLOGY AREA PLAN FOR INFORMATION SYSTEMS AND TECHNOLOGY

1. INTRODUCTION

The Information Systems and Technology (IS&T) goal is to develop the technologies and architectures needed to provide all warfighters the right information, in the right place, at the right time. To accomplish this there must be a flexible architecture that allows common software for a variety of decision making tool kits; transparent management and distribution of information among heterogeneous systems; seamless communication systems utilizing commercial and common protocols that allow transport of information anywhere in the world; computing and software technology that supports the evolution of products inserted into our common systems; and modeling and simulation (M&S) technologies for developing applications that facilitate early assessment of new technologies, supports our ability to "view" systems in the virtual world, and facilitate the utilization of application programs for training and mission rehearsal.

1.1 Definition/Scope

The Defense Technology Area Plan (DTAP) for IS&T covers the five major areas shown in Figure III.1. and is the integration of three previously reported areas from, Command, Control and Communications (C3); Computing and Software; and Modeling and Simulation. By this integration we can achieve greater focus and efficiency from our technologies and provide a common framework for integrating new technologies as they emerge. The overall concept for integrating the Services' programs in these areas is to implement the concept of a "virtual laboratory" connecting the Services' laboratories and users over high-capacity lines that allow interactive and focused experiments to take place. Utilizing this approach we will maximize the expertise in each Service, leverage Service technologies, share common products, and achieve interoperability by embracing a common architecture. Figure III.2. shows the focus of these efforts starting on the left with the warfighters needs; then utilizing the virtual laboratory to integrate programs, and finally including the Services' focused efforts in each of the five critical subareas. These subareas will be described in more detail in later paragraphs in this section of the DTAP and will be summarized in the paragraphs that follow.

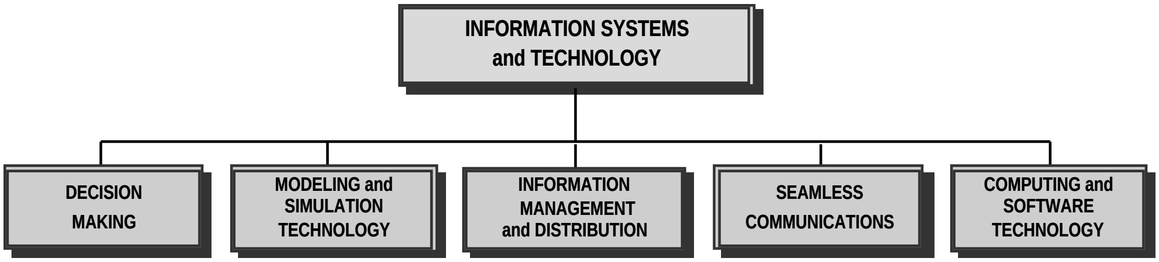


Figure III.1. Planning Structure

The efforts of these five subareas, when integrated, become effective command, control, communications, computing, and modeling/simulation building blocks that are pivotal elements of modern warfighting. They will provide the means for collaborative training, planning, mission rehearsal, decision making, information distribution, and the successful employment of accurate weapons systems. The efforts in the DTAP are the "glue" that integrates the sensors and provides the critical information to the weapons systems. Achieving this capability requires significant investment, either to leverage the commercial sector or to develop the unique military components. See Resource Appendix for funding of this Defense Technology Area.

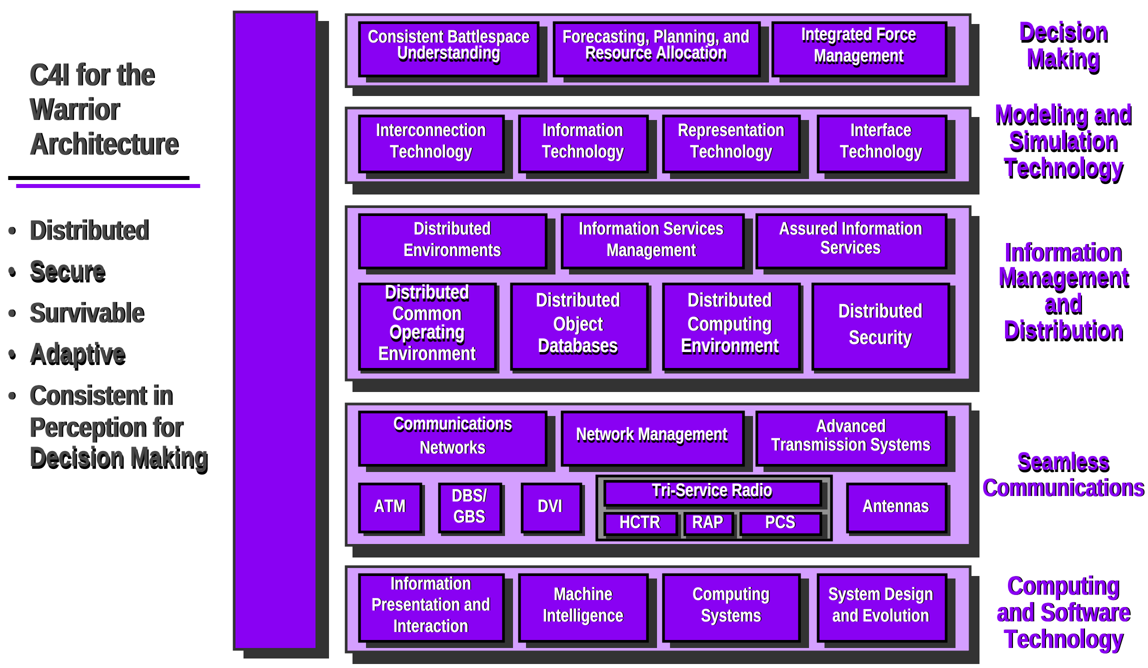


Figure III.2. IS&T Technology Focus

A brief summary of the five subareas shown in Figure III.2. follows. Decision Making is the heart of the command process. It encompasses the development of common, modular, elements that connect joint mission planning, rehearsal, execution monitoring, and common pictures of the battlespace. This will provide battlefield picture and situational assessment products that will support real time operations. M&S is a fundamental component of the other four subareas as well as supporting all other DTAP areas. M&S technologies will provide a capability for developing distributed, seamless,

interactive, and adaptive simulations through reuse and linking of a wide variety of M&S applications. Information Management and Distribution provides the information infrastructure and products needed by the other four areas (and other DTAP areas) for; information security, distributed computing, distributed multimedia databases, and visualization. This movement of information is critical to satisfying the warfighters' needs for the future. Seamless Communications spans the globe, interconnecting command echelons, Services, and allies worldwide by implementing common transport protocols and dynamic network management. By focusing on wide bandwidth capabilities linked to our narrow band tactical systems, including mitigated modems to recover messages during nuclear and natural disturbed environments, we can provide the correct critical information to the warrior anywhere in the world. Computing and Software Technology will provide an integrated approach between the private sector and the Government efforts. Focus will be on compatible software architectures; improved software tools to reduce development costs; high performance computing; intelligent agents; and user interfaces.

1.2 Strategic Goals

The top level goals of the IS&T research and development (R&D) programs are to deliver technology solutions that provide:

- Transparent communications between and across command levels/ echelons—Seamless Communications—under any weapon and natural disturbed environments.
- Common architectures as a framework to achieve transparent distribution of information.
- Commonality where common elements are appropriate (e.g., Joint decision-making tool kits)
- Readily available, operationally valid, models and simulations built to a common technical framework.
- Affordable, advanced, robust information-processing systems through effectively integrated software, hardware, and connectivity infrastructures.

IS&T programs will develop the technology to provide a real-time, fused, battlespace picture with integrated decisions aids. The technology will provide the: processing infrastructure; intelligent/anticipatory data manipulation and distribution, and dynamically adaptive algorithm, broadband communications linkages required for both command and sensor-to-shooter applications. Warfighters will be able to exchange information unimpeded by differences in connectivity, environmental conditions, processing and interface characteristics. With these capabilities we will have the ability to establish distributed, virtual staffs that share a common, consistent perception of the battlespace. The warfighter will have the capability to construct distributed task teams among command posts split between Areas of Operation and rear areas to include Continental United States with the resultant linkage of sensors, weapons, and decision

makers. Specific examples of the critical benefits provided are included in the remaining sections of the Plan.

1.3 Acquisition/Warfighting Needs

The IS&T technology efforts are critical to the stated Joint Warfighting Needs of Dominant Battlespace Knowledge; Precision Force; Combat Identification; Theater Missile Defense; Military Operations in Urban Terrain; Joint Readiness; Joint Countermine; Electronic Warfare; Information Warfare; and Real-Time Logistics Control. Figure III.3. shows the powerful technology transition opportunities to enhance the warfighters' capabilities and Figure III.4. shows the Defense Technology Objectives (DTOs) selected to provide focus for meeting these warfighter needs.

Access to and exploitation of timely information is a key element of America's future war fighting and crisis management capabilities, as well as its national competitiveness. The projected force-level-multiplier advantage of *information technology* stands far above that of all other technical areas. Such capability, while greatly enhancing the autonomy and survivability of individual units, will quickly provide an advantage in any conflict, supporting early, decisive victory with minimal cost in assets and human life.

Advanced software and computing technologies are essential to supporting the Joint Staff future Joint warfighting capabilities. As much as 90 percent of the cost of command, control, communications, computers and intelligence (C4I) systems and 80 percent of the functionality of products such as avionics systems are directly and solely attributable to software. High-performance computing and image understanding coupled with high-performance networking, distributed systems, and mobile computing form the foundations for instantaneous recognition of targets, and rapid communication of the information. IS&T also enables a wide range of defense-critical applications, such as new methods for design enabled by computational models in many science and engineering disciplines. Advanced M&S tools and simulation-based training systems offer more cost-effective means of enhancing individual and unit performance, as well as conducting assessments, analyses, and rehearsals. For modernization, M&S technology will reduce the time, resources, and risks of the acquisition process while enhancing the performance of the acquired systems. Virtual prototypes will be evaluated in realistic synthetic acquisition and operational environments, supporting the many phases of the acquisition process from requirements definition and initial concept exploration to the manufacturing and testing of new systems.

Many of these advances in IS&T are being driven by commercial developments and products. The results can be brought to bear on Department of Defense (DoD) problems through cooperative efforts and participation in efforts to set standards and establish policy. Costly DoD-specific development can be avoided with the amortization of costs across Government and commercial communities. However, there are aspects of command, control, communications, and computers (C4) and M&S that must be strongly influenced or directly supported by DoD. In particular, developing the capability to reliably communicate to and among numerous, widely dispersed mobile sites operating in actively hostile environments; identifying friend and foe; achieving information security; and meeting the requirements for military-unique processing and decision support systems will not be achieved without significant DoD support. The IS&T acquisition

strategy is necessarily a pragmatic one—identify the pivotal issues, capitalize on commercial development whenever feasible, leverage development in areas with special military aspects, and sponsor programs in technologies with unique DoD interest that would otherwise not be available to meet DoD needs.

Technology Subarea	Years: Current Baseline	5	10	15
Decision Making	Time consuming and manually intensive planning.	Semi-automated situational assessment, planning, and resource allocation	Automated decision aids with 3–D perspective for both information and battlespace increase understanding.	Fully integrated GCCS applications that are scalable and tailorable to platform, echelon and warfighter.
.	Limited Interoperability among C2 systems. Limited battlefield visualization Few real-time aids, Service-specific systems & tools	Hyperlink, integrated, sensor and situational 3–D information displays Near real-time 2–D/3–D visualization Collaborative, Joint framework in-place for automation and COE products.	Hyperlinked information shared among C2 systems promotes rapid cognition. Fully automated COE applications for assessment, planning, and monitoring	All-source hyperlinked information adapted to individual Joint, common core planner. Compatible w/COTS, DSS and EIS products.
Modeling and Simulation Technology	One-of-a-kind, stovepiped models and simulations cost too much and take too long to build. Some interoperability available through ALSP and IEEE DIS.	Interconnection and information technologies applied to M&S applications currently under development. Simulation generation technologies reduce development costs by a factor of 10 and development time by factor of 5.	Simulation interoperability is expanded throughout the Services and across the training, acquisition, and analysis communities. MLS capabilities provide a broader range of M&S tools	Simulation interoperability is optimized. Legacy systems (those developed prior to FY96) are either interoperable or no longer in the simulation community.
	Environmental databases lack interoperability, reuse, and rapid generation across all domain areas (terrain, ocean, atmosphere, and space). Representation of human behavior (especially C2) is not available.	72-hour generation of cost-effective, high-resolution, small-area-coverage terrain environments. Environmental input to JSIMS and JWARS, supported by standard data. Human behavior C2 modeling at battalion and company level.	Fully documented terrain, ocean, and atmosphere databases within 72 hours covering required maneuver areas. Human behavior C2 modeling at brigade, division, and Corps level.	Able to generate and interface databases of differing resolution in live, virtual, and constructive simulations for all environmental domain areas. Full representation of both individual and group behavior for M&S applications.
	Use of M&S by live forces to plan and rehearse missions is limited by lack of adequate C4I-simulation interfaces.	C4I-simulation interfaces for limited mission planning and rehearsal.	M&S applications readily available to fielded forces for mission planning and rehearsal.	Simulation augments operational warrior.
Information Mgmt. and Distribution	Interoperable DCE	Hybrid real-time/non real-time DCEs interacting with mobile DCE clusters	Real-time multimedia object-oriented DBMSs with mobile clusters	Adaptive intelligent DCEs used for training, simulation, and warfare
	Battlefield data distribution not echelon aware	End-system aware self-striping multimedia objects	Information. distribution that is cognizant of echelon, spatial, and temporal issues	Seamless C-in-C-to-foxhole information distribution
	Homogeneous, secure system component solutions	Composable COTS for secure systems solutions	Secure, high assurance distributed computing environments	Automated security policy maintenance with adaptive security structures
	Mechanisms for fault tolerance	Intelligent fault recovery	Automated replication and distribution of assets	Self-healing systems with predictive fault avoidance
Seamless Communications	Separate circuit, packet, and message switching networks, 2 Mbps stationary trunk radios, tactical Internet	Limited ATM—utilized for multimedia applications, 45 Mbps trunk stationary radios, IPng, mobile IP, multicast	ATM/ISDN upgrades to wide-area systems, 45 Mbps OTM trunk radios, wireless ATM	Tactical B-ISDN, 155 Mbps OTM trunk radios, 600 Mbps stationary
	Experimental DBS/GBS	23 Mbps GBS, limited in-theater injection	23 Mbps GBS, global theater injection	Military GBS with high-data-rate reachback
	Single-channel radios with limited-programmability	Speakeasy/FDR	Smart radio functions for FDR	Universal digital radio (PC of communications)

NOTE: See acronym list at the end of the chapter.

Figure III.3. Information Systems and Technology Transition Opportunities

Technology Subarea	Years			
	Current Baseline	5	10	15
	Experimental range extension trials, no advanced warning of communications blackout	Range extension via relay of opportunity and mobile networks, prediction of blackouts due to adverse environments	Medium-endurance, communications relay UAV	High-endurance, communications relay UAV
Computing and Software Technology	Limited application of reusable software components	Software developed component by component with extensive use of COTS/GOTS for SC-21, JOINT STARS, NSSN, DSP, Cheyenne Mtn., AEGIS, and THAAD	Domain specific development through specification process only—for Joint Task Force (JTF) C2, flight simulators, and UAVs	Warfighter-modifiable systems—for ATR, THAAD, JTFC2, and UAVs
	Autonomous devices operating independently	Team tactics demonstrated for autonomous multi-agent behavior for hazardous operation in vehicle maintenance, unmanned vehicles, and information fusion	Plan creation and execution among cooperating intelligent robots for mine clearing, UAVs, information collection, and fusion	Self-initiated plan creation and execution among cooperating intelligent robots for space system repair, unattended systems, and mine sweeping
	Heavily tethered, limited interaction, single-user VR displays	Tether-free, multiple-user, single-discipline interaction with 10K word vocabulary for mission rehearsal, and mission planning applications	Single-user, immersible VR with 50K word vocabulary in multiple-discipline collaboration for JTF, mission simulation, rehearsal, planning, and execution	Multiple-user, real-time VR for telepresence and UAV mission training
	10 GFLOP/cubic foot, militarized	100 GFLOP/cubic foot, militarized for enhanced AEGIS and THAAD	TFLOPS/cubic foot, militarized for space-based DEW, ATR, sensor/knowledge fusion, and autonomous UAVs	100 TFLOPS/cubic foot, militarized for real-time situational awareness in the cockpit

Figure III.3. Information Systems and Technology Transition Opportunities (cont.)

This technology area embodies enormous dual-use potential in numerous areas vital to economic competitiveness and other national concerns. Beside the direct application of this technology to defense sciences and engineering, it has great potential for significant contributions to more effective health care procedures, enhanced education and lifelong learning, more timely and less costly procurement through electronic commerce, more efficiently managed and integrated transportation networks, the delivery of innovative information services to average citizens, and sound methods of environment monitoring, weather prediction, and pollution control. For example, approximately 80 to 90 percent of DoD's investment in computing and software technology can be credibly regarded as having substantial dual-use potential by even the most conservative of individuals.

2. DEFENSE TECHNOLOGY OBJECTIVES

The figure below identifies the DTOs approved for IS&T by number and shows which subarea in the IS&T area is responsible for the DTO. A write-up on each DTO is provided in Appendix A. These DTOs were selected not only for their importance to the total DoD tech base effort, but also for their integrative support across this DTAP area.

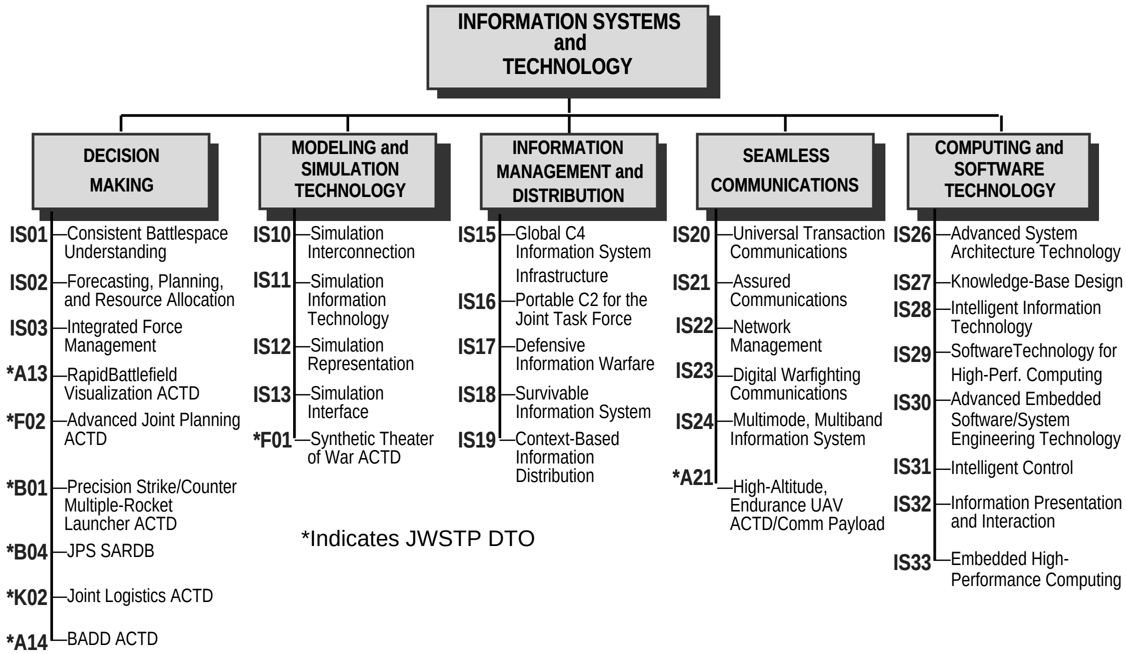


Figure III.4. Taxonomy of DTOs

3. TECHNOLOGY DESCRIPTIONS

3.1 Decision Making

3.1.1 Warfighting Needs

The Decision Making subarea focuses on all elements of the decision making process from tactical assessment, through plan preparation, deconfliction, rehearsal and execution. The major emphasis is on acquiring and assimilating information needed to dominate and neutralize adversary forces. This includes capability for near real-time awareness of the location and activity of friendly, adversary, and neutral forces throughout the battlefield area, providing a common awareness of the current situation. One of the primary objectives of information dominance is to meet the warfighters' needs for a flexible command structure that can be configured rapidly and dynamically adapted to optimize force effectiveness and survivability. This subarea applies leading-edge M&S, and computing and software technology to significantly improve warfighter performance by eliminating laborious, time-consuming manual procedures and processes that pervade US operational planning and execution. Computer-aided processes and automation-synergistic procedures replace exclusively human processes and procedures. The warfighter is provided with an intuitive view of his battlespace, an enlightened perspective of his information (Command and Control [C2], intelligence, logistics, weather, and other critical data), and the ability to explore alternatives in faster-than-real-time (e.g., exploring 10-hour battles in several minutes).

3.1.2 Decision Making Overview

3.1.2.1 Goals and Timeframes. The goal is to provide automated, real-time decision support to the warfighter. The warfighter must rapidly interpret information provided to him through interactive two dimensional (2–D)/three dimensional (3–D) presentation of the tactical situation (situational assessment cues identifying potential problems or interest areas). The Commander must view (from a situational assessment display) relevant forecasts for weather, enemy strength over time, friendly strength, logistics tail, to conduct course of action (COA) analyses, allocate resources, wargame (real-time simulation) to explore battlespace options, and collaboratively plan and rehearse battles. Such a capability will result in the precise direction of a diverse, synchronized task force armed with overpowering information superiority and decision making capability. Figure III.5 shows the goals and time frames for the Decision Making subarea. A roadmap that focuses on the linkages and key relationships is provided in Section 4.

Short-Term (97-98)	**Mid-Term** (99-01)	**Long-Term** (02+)
Integrated multi-sensor air/land/sea picture on digital maps (theater and national products) with hyperlinks to multimedia information products	Scalable, battlefield visualization shared across the Joint force for plans, logistics, weather; real-time friend/enemy situational representation	Fully automated, multi-dimensional, tailored, “virtual battlefield view” (100 percent consistent across echelons, measured against time)
Semi-automated, collaborative situational assessment. Semi-automated identification and force analysis tools.	Partly automated situational reasoning, target and threat analyses, decision making under uncertain conditions; automated “situation server” demonstration to support planning, replanning, pattern recognition, tactical picture management, intelligent cueing	Fully automated situation reasoning supported by multimedia techniques for sensor-shooter targeting, combat identification, multi-hypothesis data fusion, and resource allocation under uncertain conditions
Planning systems of differing architectures interconnected for theater COA, campaign plan, battle plan, force-level air-mission plan preview in less than 12 hours	Cognitive decision support for distributed situational assessment, supported by dynamic 3–D virtual battlefield displays	Automated situation projection. Fully automated links to planning, rehearsal and other Decision Making tools. Automated warfighter cueing to prioritized issues
Automated, air operations planning aids. Semi-automated applications for COA analysis, time and event-based forecasting, route planning, and limited resource allocation functions	Demonstration for distributed, cooperating agents and algorithms for COA generation and crisis response, automated plan generation, plan deconfliction, resource allocation, targeting, and weaponeering	Joint, common-core mission planner with Service-unique modules. Compatible with COTS DSS and EIS products.
Near-real-time, semi-automated dissemination of mission tasking and time-critical information. Use DBS/GBS with enroute C4I updates for replanning and rehearsal	Fully integrated collaborative planning (planning support from remote anchor desks, split-base operations for logistics and asset visibility); distributed, in situ mission rehearsal	Fully automated, real-time situational assessment, forecasting, plan generation, resource allocation including weapon/target pairing, and mission rehearsal
Demonstrate air battle plan repair for up to 25 percent of sorties contained in original plan	Real-time, automated dissemination of mission tasking, mission status and time-critical information. 2–D and 3–D perspective displays to aid rapid understanding of battlespace (less than 1 hour)	Fully interactive, distributed wargaming
Limited real-time alerts or “pointers” to identify problem areas or areas of interest	Replan entire missions across single echelon in less than one hour; integrate effects and constraints assessment from total asset visibility status changes	Integrated all-mission, all-echelon replanning and execution (2,500-sortie integrated ATO regenerated and retasked at 1-hour intervals). Fully automated and tailored displays based on echelon, mission, region and other factors. Extensive use of intelligent agents.

Figure III.5. Decision Making Goals

3.1.2.2 Major Technical Challenges. The major challenges are: develop applications that employ intelligent agents for intelligent information retrieval, fusion and presentation; fuse planning information with actual information in real time; provide real-time simulation (wargaming), planning, and rehearsal with sufficient fidelity on tactical platforms to influence battle outcomes; provide decision support in the presence of uncertain, incomplete or absent information; develop applications for dynamic scheduling/coordination of assets for inter-dependent tasks; and provide collaboration tools that permit the spectrum of operations to be performed by remote, dispersed elements of a task force.

3.1.2.3 Related Federal and Private Sector Efforts. There are a multitude of efforts, both federal and private, which relate to this subarea. Private investment is this subarea spans virtual reality (VR), decision aids, decision support systems, executive information systems, advanced database engines, and related technologies and is estimated to be $1,400M.

3.1.3 S&T Investment Strategy

3.1.3.1 Technology Demonstrations. Technology demonstrations scheduled for FY96 with the XVIII Airborne Corps (XVII ABC) and U.S. Atlantic Command (ACOM), and the Army's Task Force XXI (TFXXI) experiment, include collaborative planning, 2–D/3–D visualization and mission rehearsal, force synchronization and dynamic force monitoring. Several other technology demonstrations are scheduled under the technology areas of Consistent Battlespace Understanding, Forecast, Planning, and Resource Allocation, and Integrated Force Management. Specific Advanced Concept Technology Demonstrations (ACTDs) are highlighted below, other technologies initiatives are discussed under Technology Development (3.1.3.2).

3.1.3.1.1 Survivable Armed Reconnaissance on the Digital Battlefield (SARDB) ACTD. The purpose of this ACTD is to demonstrate how advanced concepts and technologies will enhance the warfighter's capability to conduct armed reconnaissance across the joint battlefield. Through the use of constructive and virtual simulation, coupled with prototype systems, the combined effects and tradeoffs between UAVs and reconnaissance helicopters will be determined. The full potential of Comanche in a Joint RSTA environment will also be examined. A three-year series of demonstrations beginning FY97 will quantify the requirement for armed reconnaissance.

3.1.3.1.2 Advanced Joint Planning (AJP) ACTD. AJP will provide ACOM, Joint Staff and other Commander-in-Chief (C-in-C) elements with an increased ability to rapidly plan, package and deploy forces to multiple regional conflicts. The three primary areas of focus are on force readiness and deployment planning, force employment planning, and force rehearsal and evaluation. Technologies developed by the Advanced Research Projects Agency (ARPA) and others will be tailored for this purpose, integrating and evolving operational concepts in close collaboration with operators and sustainers. This new functionality will provide a supported, leave-behind capability at ACOM before being transitioned through the Defense Information Systems Agency (DISA) Global Command & Control System (GCCS) Leading Edge Services (LES) into the GCCS core service for application with other users.

3.1.3.1.3 Precision Strike/Counter-Multiple Rocket Launcher (MRL) ACTD. The Joint Precision Strike Demonstration (JPSD) Program Office established the Counter MRL ACTD to improve the capabilities of Combined Forces Command(CFC)/United States Forces Korea, (USFK) to execute a critical counterfire mission against the North Korean 240 mm MRLs. Enhanced capabilities in surveillance, target acquisition, strike planning, weapons delivery, and combat assessment will be demonstrated for use by the 2nd Infantry Division (2ID). In FY 96 systems defined as "leave-behinds" will be delivered to USFK, followed by two years of support. The leave-behind systems will be tested in a series of three major demonstrations with the last one conducted in USFK.

3.1.3.1.4 Battlefield Awareness and Data Dissemination (BADD) ACTD. BADD will demonstrate advanced information integration and intelligent filtering, and high bandwidth satellite communications, to provide a consistent operational picture extending from the tactical to theater levels, with different aggregations and views into the information for each echelon. The technology demonstrations emphasize advanced techniques for fusing, displaying and aggregating relevant, multimedia information. One component, the Army Common Ground Station (CGS) ATD, builds an all-source picture and makes it available at lower echelons. BADD will base its Warfighter's Associate workstation on CGS technology, and will employ advanced, higher-level applications for data and tactical visualization developed from the Army's technology base program (below).

3.1.3.1.5 Rapid Battlefield Visualization (RBV) ACTD. The RBV ACTD will demonstrate the ability to respond swiftly to any global crisis, by rapidly mapping and developing a high-resolution digital map of the area of operations, and then employing that map in an advanced C4I visualization system. The RBV workstation will display terrain features, C2 environmental, cultural, logistical and other relevant information in a 3-D VR. The RBV workstation is a functional equivalent of the BADD Warfighter's Associate and where appropriate, they are the same machine. Application modules for these workstations will be imported from the Battlespace Command and Control (BC2) ATD. These include situational assessment; forecasting; COA analyses; collaborative battle planning, replanning, and rehearsal; wargaming; and execution monitoring. Current iterations of the BV workstation are providing a limited set of the aforementioned functions to the XVIII ABC and ACOM in a series of live exercises. BC2 ATD will support the RBV ACTD in demonstrating multi-echelon, multi-service, multi-national interoperability amongst C4I systems above.

3.1.3.1.6 Joint Logistics ACTD. The goal of the Joint Logistics ACTD is to provide C-in-C and CJTFs with planning tools to assist them in becoming more efficient and responsive to the demands of logistics support. This will be accomplished by a network of workstations connecting operational planners and logisticians across Services and echelons. This ATD integrates existing logistics models with knowledge based tools. The Total Distribution (TD) ATD is a technology demonstration supporting the Joint Logistics ACTD. It will provide the connection between C4I and logistics for the processes of situational assessment, planning and execution. The TD ATD is the primary demonstration of the Joint Logistics interface, but the technology is being demonstrated in close coupling with the ARPA Joint C4I infrastructure and with other technology demonstrations discussed above.

3.1.3.2 Technology Development. Decision Making is comprised of three major technology areas: Consistent Battlespace Understanding (CBU); Forecasting, Planning and Resource Allocation (FPRA); and Integrated Force Management (IFM). When integrated, they represent the fundamental C4I processes of "assess, plan, and execute." Technology is being actively pursued to achieve the goals outlined in Figure III.5, above.

3.1.3.2.1 Consistent Battlespace Understanding. CBU is developing a capability to continuously acquire and fuse multi-sensor, multi-source, multimedia data to form a coherent tactical picture. This tactical picture includes awareness of the overall theater and tactical situations of friendly, enemy, and neutral forces and an understanding of the constraints and environment in which they operate. Improved assimilation of the tactical situation information will reduce casualties and fratricide, while ensuring a dominant posture for friendly operations.

Precision Information Direction (a part of CBU) demonstrates technology that enables the commander to exploit and shape the battlespace by dynamically directing and integrating tactical and supporting intelligence, surveillance, and reconnaissance resources for targeting, weaponeering, mission preview, battle damage assessment (BDA), and combat assessment. This capability provides end-to-end, task-synchronized, multi-mission support products to the warfighter to facilitate the application of precision weapons, precision forces and rapid response. Some technical challenges are collection, exploitation and organization of information, quality assessment and correlation of information, intelligent filtering and preparation of information, fusion of the picture, presentation of the picture, and automated, collaborative situation awareness.

3.1.3.2.2 Forecasting, Planning and Resource Allocation. FPRA is developing and will demonstrate a planning system that provides a core of integrated planning tools to support the generation of Joint plans across echelons, Services, and mission areas. The goal is a 75 percent common planning system across the Services, with a capability for Service-unique applications that jointly plan the allocation and scheduling of resources in pursuit of a common mission objective. In collaborative planning, the impacts of planning at one site are reflected at other sites to support coordination, deconfliction, and group decision making. An objective is to achieve collaborative planning across distributed force and mission areas, within a one hour planning cycle, and refine, deconflict, review, preview, evaluate, finalize, and update integrated plans within three hours.

Predictive Planning and Preemption, and Incremental Force Projection (parts of FPRA) focus on distributed opportunity planning processes which provide look-ahead, multi-option optimization to the offensive and defensive strategy across time, space, resources and spectrum. Subsets of this process include: collaborative, combined-arms crisis assessment, target selection and continuous plan generation, collaborative plan refinement, deconfliction, and evaluation, and the ability to rapidly tailor systems and updates as stimulated by threat actions. Other activities on-going in FPRA designed to overcome existing technical challenges are Mission Planning and Mission Rehearsal, Joint Force Commander and Joint C4I Infrastructure, and Theater/Force Battle Management. Mission Planning/Rehearsal technology initiatives support forecasting and Course of Action (COA) generation through a series of activities to include near real time updates, mission evaluation, and wargaming. The Joint C4I infrastructure is being developed under the auspices of two ARPA technology demonstrations, Portable C2 for

the JTF ATD (see the section on Information Management and Distribution), and Advanced Joint Planning ACTD (discussed in detail above under technology demonstrations). Theater/Force Battle Management is comprised of the Operations/Intelligence ATD and the Defensive Planning ATD. These ATDs implement a campaign strategy at the force level where technologies focus on resource allocation, scheduling, flow modeling and systems architectures.

3.1.3.2.3 Integrated Force Management. IFM is developing a capability to synchronize and manage the execution of tactical operations across Joint Forces. The goal of this effort is to achieve fully synchronized friendly-force situational awareness and coordination, including real-time retasking and retargeting (with cued, "just-in-time" delivery of latest and best information) between distributed sensors, decision makers, and shooters. Fully coordinated operations across the force will result in faster adjustment of mission plans in a dynamic tactical environment and a reduction in casualties and fratricide.

Adaptive Coordinated Defense (a part of IFM) is developing a capability to integrate offensive and defensive systems across services into a collaborative strength which exploits real-time retasking, thereby optimizing resources and coverage, and taking advantage of "distributed empowerment". This supports force-wide coordination of scheduling, placement, dynamic tasking, and retasking of detection/engagement assets. Tactical Mission Execution will be accomplished as the result of the work being conducted in two ATDs, the Local Attack Controller (LAC) ATD and the Real-Time Support for Joint Power Projection ATD. These ATDs focus on the integrated planning and execution of coordinated operations at the tactical level (e.g., brigade, wing, battle group, and below) and explore detailed platform, weapons, and target models, in addition to sophisticated optimization algorithms for achieving synchronized, coordinated tactics. Simulation support focuses on detailed event rehearsal and effectiveness evaluation versus aggregate-level attrition assessment. Some challenges for execution management are dynamic, broad-ranging monitoring and synchronization, resource reassignment and execution deconfliction, dynamic sensor to shooter targeting, plan repair, execution coordination, and context-based intelligence.

3.1.3.3 Basic Research. There are several critical ongoing research efforts required to meet the challenges of Dominant Battlespace Knowledge, Precision Force, Joint Readiness, and Real-Time Logistics Control. Rule-based, knowledge-based and Artificial Intelligence (AI) modules are required that can provide the intelligent agent functions for a broad spectrum of applications with imperfect data. Also required are 3–D rendering algorithms that permit perspective viewing on a range of computer platforms from low to high-end, and interactive force-on-force wargaming models to permit real-time simulation of potential battle actions and to explore related options.

3.2 Modeling and Simulation Technology

3.2.1 Warfighter Needs

M&S complements and augments warfighter needs and capabilities across all IS&T subareas, and several other DTAPs and Joint Warfighter S&T areas (i.e., Military Operations in Urban Terrain (MOUT) and Joint Countermine). Advanced M&S tools

and synthetic environments offer more effective and less resource intensive means of enhancing individual and unit performance. M&S can substantially contribute to improving the pillars of military capability—readiness, modernization, force structure, and sustainability. M&S will enable cost-effective Joint and combined training, mission planning, and mission rehearsals involving active and reserve forces, multiple echelons, and computer-generated simulations of large-scale forces (friendly, neutral, and hostile) on a synthetic battlefield. These distributed, interactive, synthetic environments will bridge large geographic regions and involve entire Joint forces from senior commanders to individual warriors. The use of M&S will reduce time, resources requirements, and risks associated with the acquisition process. Representations of proposed systems (virtual prototypes) will used to support acquisition activities, significantly reducing the time and expense of concept exploration, engineering, manufacturing, and follow-on support activities (e.g., training, maintenance). Decision makers can effectively and quickly simulate and then evaluate the consequences of alternative force structures with known or projected capabilities placed in various mission scenarios. High-fidelity models of logistics, personnel management, medical support, etc., will be integrated with combat models to allow a comprehensive analysis of sustainability.

3.2.2 M&S Technology Overview

3.2.2.1 Goals and Timeframes. M&S core technologies must provide a cost-effective and timely capability to authoritatively represent systems, processes, and operational environments. M&S must provide readily available and operationally valid environments for DoD components to: train jointly; develop doctrine and tactics; formulate operational plans; assess warfighting situations; support technology assessment, system upgrade, and system development; and conduct force structure analyses and assessment. Research is needed to more broadly and authoritatively apply models and simulations across all of DoD. Supporting technologies are being developed in other subareas of the IS&T technology area, as well as in other DoD technology areas (e.g., Human Systems, Sensors and Electronics, and Materials/Processes) and in the commercial sector. Major M&S efforts are in the areas of: (1) Simulation Interconnection, (2) Simulation Information Technologies, (3) Simulation Representation, and (4) Simulation Interfaces. The efforts of interest concentrate on the technologies that bring about distributed, seamless, interactive, and adaptable models and simulations. Efficiency is gained through sharing, reuse, and standardization of data and common data structures; models and algorithms; data exchange protocols; M&S services; improved exercise generation and control; interfaces; and network communications. The M&S goals are shown in Figure III.6 below. A roadmap that focuses on the linkages and key relationships associated with the corresponding DTOs is provided in Section 4.

	Short Term (97–98)	**Mid Term** (99–01)	**Long Term** (02+)
Interconnection	Complete high-level architecture prototype testing; baseline high-level architecture; prototype runtime infrastructure software; prototype federation development tools for accessing MSRR and developing federation object models; first generation object interaction protocols and standards test procedures; alpha level software for application dynamic multicasting technologies; demonstrate distributed exercise technologies.	High-level architecture compliance testing tools; second generation protocols and standards test procedures; dynamic multicasting grouping software.	Scalable and variable resolution models; 100,000 heterogeneous entities interacting in various dynamic multicast groupings
Information:	Initial consistent, conceptual models of the mission space prototype; second-generation data interchange format for critical sub-categories of five M&S data areas (scenario, doctrine and operations, environment, equipment, and force description); accreditation support services methodology.	Conceptual models and problem domain models visualized graphically using advanced, manipulatable 3–D models; conceptual information retrieval based solely on graphical or iconic inputs; 50 percent of warfighter validation of doctrine, functions, tactics, techniques, and procedures using conceptual models of the mission space; Data interchange formats incorporate emerging, complex data structures from highly derived data, and allows object-oriented data to be passed across all M&S data areas; prototypes of simulation system support tools.	CMMS conceptual models represent 50–60 percent of DoD activities; warfighters have worldwide access to conceptual models of DoD processes; evolutionary data interchange format products that support all data elements for the M&S community; data security; sophisticated complex data modeling techniques, tools, and structures
Representation	Initial capability to generate a 2,500 square kilometer M&S terrain database within 72 hours to meet identified crisis mission rehearsal requirements; database testbeds used for specifying interfaces among terrain, ocean, and atmosphere environments; roadmap for modeling human behavior.	Full capability to generate a 2,500 square kilometer M&S integrated terrain, oceans, atmosphere, and space database within 72 hours from multiple sources; interconnection of environmental models of different resolution; MSRR system access to all environmental data; authoritative system representations coordinated across DoD; representation of human C2 decision-making process to company and battalion surrogates.	Tools for dynamic, scalable (micro to macro) adjustment to representations within and among simulations that run in real time; interface specifications for seamless, consistent, synthetic environments; libraries of entity models; effectively represent the human C2 decision-making process for brigade, division, and Corps surrogates.
Interface:	Technical requirements for human-simulation interfaces across DoD; prototype distributed environment for C4I-simulation linkage.	First-generation prototype of dismounted warrior immersion in synthetic environment; multiplexed tactical data link and simulation; reusable linkage technology between simulations and real-world C4I systems; simulation linkages to design and manufacturing systems.	Full immersion of all live players into virtual world

Figure III.6. Modeling and Simulation Technology Goals

3.2.2.2 Major Technical Challenges. For interconnection, the major technical challenges include: (1) establishing the architectural design, protocols and standards, multilevel security (MLS), and use of dynamic multicast groups for the interoperability of simulations, (2) providing the maximum possible interoperability among simulations at different levels of resolution and (3) establishing application gateways, time management services, servers, and translators that will provide common services to all simulations. The ability of emerging commercial network services and products to meet critical M&S needs must be examined.

Developing coherent, complete, and consistent Conceptual Models of the Mission Space (CMMS) is also a difficult task. CMMS is an abstraction of Joint mission essential tasks list that serves as a frame of reference for M&S development by capturing the features of entities involved in any mission and their key actions and interactions. DoD M&S spans a wide range of missions (from unconventional to other than war missions) and M&S applications (from system acquisition activities to mission planning and rehearsal). The need for valid quantitative assessments of effectiveness and performance will lead to the collection of classified data. The distributed and interactive nature of

advanced M&S capability make the standardization and securing of data an extremely complex technical concern.

Representations of terrain, the ocean, the atmosphere, and space must span large and diverse regions and must account for a large number of significant conditions and effects. Major challenges include the rapid generation of and near real-time interaction of these representations. New object-oriented, multi-spectral representations of synthetic environments are needed to enhance M&S support to battlefield awareness systems. The representation of human behavior must reflect human capabilities, cognitive processes, limitations, and conditions that influence behavior (e.g., morale, stress, fatigue). Providing *variable* human behavior for friendly, enemy, and non-hostile personnel remains a significant challenge.

Interfaces between live systems and synthetic environments must overcome two problems: (1) the interfaces between live systems and synthetic environments must be responsive and complete, and, (2) representations of live systems in synthetic environments and synthetic forces in live systems are needed to provide a consistent and coherent exercise.

A key challenge for supporting training while on the move (OTM) is providing responsive interfaces to synthetic environments for personnel using real C4I systems. OTM distributed M&S capability for training is challenged by the bandwidth capability available from the tactical communications systems.

3.2.2.3 Related Federal and Private Sector Efforts. DoD is leading in M&S interconnections, as well as in representations of the environment and systems. Other Government agencies such as Department of Transportation, Federal Aviation Administration, National Highway Traffic Safety Agency, Department of Justice, Federal Emergency Management Agency, and related state and local governments use distributed M&S to accomplish their missions and participate in the development of Distributed Interactive Simulation (DIS) standards. Both DoD and the commercial sector are heavily involved in efforts to standardize M&S information/data. DoD has the lead in the development of CMMS, the management of complex data, and the analysis and assessment of simulations. The private sector is addressing the modeling and simulation of individual and group behavior in terms of market research efforts and in evaluating combined human and system performance (e.g., automotive sector). DoD, other Government agencies, and the commercial sector are all heavily involved in M&S interfaces (e.g., DoD training systems, commercial entertainment interfaces, commercial design and manufacturing interfaces). DoD is leveraging industry's advances in visual displays, graphics quality, and the application of M&S in design and manufacturing.

3.2.3 S&T Investment Strategy

3.2.3.1 Technology Demonstrations. M&S is used as a tool in all of the DoD technology areas to support conceptual analysis, technology development, acquisition, testing, fielding, sustainment, operational effectiveness, training, and planned product improvement, and is thus demonstrated in concert with most current DoD technology developments. Although all Services and Agencies are developing M&S applications, most of these enabling technology development efforts are funded by the Defense Modeling and Simulation Office (DMSO), ARPA, and the Army. Demonstrations of

M&S are oriented toward showing advances in the application of M&S as a tool. Demonstrations are grouped according to the M&S DTOs.

Proto-Federation	Member Programs
Platform Federation	BFTT, JTCTS, BDS-D, STOW, CCTT
Joint Training Federation	Eagle, JSIMS, NASM, NSS, DEEM
Analysis Federation	JWARS
Engineering Federation	JMASS, T&E-EW, SBD, IADS

Figure III.7. Initial Proto-Federation Groupings

3.2.3.1.1 Simulation Interconnection Demonstrations. A complex of programs were selected as candidate "proto-federations" for the purposes of demonstrating a high-level architecture (HLA) prototype. These programs are grouped in the proto-federation based on a combination of technical issues being addressed, characteristics of the member programs, and common mission interests. The initial grouping are shown in Figure III.7. As an ACTD, Synthetic Theater of War (STOW) 97 will be the first DoD program to be totally committed to demonstrating High Level Architecture as its architecture.

3.2.3.1.2 Simulation Information Technologies Demonstrations. By FY96, CMMS prototypes should be completed for use in the M&S development process. The use of CMMS prototypes will be demonstrated in STOW-97 and in the development of Joint Simulation System and Warrior Simulation for the year 2000. Additionally, common DIFs will be available to reduce the time it takes to move the data from the data producer to the data user and to enhance M&S interoperability through the Data Interchange Format (DIF) and the larger DoD data standardization effort.

3.2.3.1.3 Simulation Representation Demonstrations. Authoritative representations of the environment will be demonstrated in many initiatives over the next few years. A surf zone demonstration will integrate atmosphere, terrain, and ocean databases. The Interferometric Synthetic Aperture Radar (IFSAR) will demonstrate the use of high altitude radar to acquire data to support the Digital Terrain Elevation Data (DTED) program. The Defense Mapping Agency (DMA) has many pilot projects to demonstrate the fusion of data from various sensors to develop high-resolution databases. The nomination and adoption of authoritative representations of systems will begin soon. Initial plans for developing human behavior representations will be coordinated with some of the nation's top behavioral scientists.

3.2.3.1.4 Simulation Interface Demonstrations. The Rapid Force Projection Initiative ACTD (DTO B02) will use force-on-force simulations to progressively demonstrate incremental enhancements in live-synthetic environment interfaces culminating in an integrated live-virtual demonstration in a DIS environment. JWID will demonstrate the use of distributed collaborative planning and M&S services over a wide range of C4I systems from C-in-C/CJTF level to unit level.

3.2.3.1.5 Synthetic Theater of War ACTD. The STOW ACTD will demonstrate the use of a synthetic battlespace to support joint training and mission rehearsal, based on entity-level representation of platforms and interactions. The STOW

ACTD program is extending and integrating core simulation technologies, including synthetic forces, synthetic environments, and real-time networking and information transfer. Specific advances include computer representation of C2 nodes (CFOR program); the incorporation of weather, phenomenology, and dynamic terrain in the synthetic environment; multi-casting software and hardware and fast encryption devices to support large-scale exercises. Additional objectives include interfacing operational C4I systems into the STOW system advanced exercise control and after-action-review and analysis tools aimed at reducing the overhead cost of using simulation. STOW also serves as an early prototype of the HLA and the CMMS initiative.

3.2.3.2 Technology Development. M&S supports and draws on the advances in all of the IS&T sub-areas, as well as in other technology areas. Within the IS&T technology area, M&S will benefit from advanced developments in seamless communications, information management and distribution, and computing and software. M&S will not only benefit from technology developments in decision making, but M&S will be a key element in advancing the "state-of-the-art" in that sub-area. Closely related R&D activities efforts, in other DoD technology areas, that specifically support M&S-enabling technologies include: (1) the modeling of environments in Sensors and Electronics that supports the development of physics-based authoritative representations of terrestrial, ocean, lower atmosphere, and space/upper atmosphere environments; (2) the Human Systems technology area efforts that will complement and support the development of the human-simulation interfaces; and (3) the simulation-manufacturing interfaces being developed in the Materials/Processes technology area. The M&S development efforts that will be supported within the M&S subarea or coordinated in other sub-areas/technology areas, include the following technology development efforts:

- High-level architecture
- Application support services
- Dynamic multicast grouping technologies
- Data structures, dictionaries, enumerations, and interchange formats
- Simulation system support tools
- Authoritative representations of the environment
- Simulation-C4I interfaces
- Authoritative representations of human and group behavior
- Authoritative representations of systems
- Network communication services
- Protocols and standards
- Conceptual models of the mission space
- Complex data modeling techniques, tools, and formats/structures
- Simulation analysis and assessment
- Simulation-instrumented live systems interfaces
- Human-simulation interfaces
- Simulation-design and manufacturing interfaces

3.2.3.3 Basic Research. The ongoing development of efficient mathematical algorithms is needed to enhance the performance of modeling and simulation. To enhance the ability to create, maintain, and exploit distributed simulation systems, ongoing basic research is in auto-code generation, real-time distributed databases, automated knowledge capture, dynamic data probes, plan representation techniques, and intelligent software agents. Behavioral science research supports the development of authoritative representations of individual and group C2 behavior.

3.3 Information Management and Distribution

3.3.1 Warfighter Needs

This subarea encompasses Warfighter needs and capabilities related to information warfare (IW) and information systems. IW and information systems include information, information based processes, information systems and computer based systems either individually or in combination with each other. The Joint Chiefs of Staff (JCS) C4I for the Warrior Initiative describes a global infosphere providing the right information, at the right time, in the right place. The key to providing this capability is a distributed information management and distribution system that forms the backbone information infrastructure of all future C4I systems. Many capabilities (not currently available) will be an integral part of this information environment. Providing technologies that allow automated, adaptive, and robust information resource management, means we can free up the warfighter from the mundane and tedious tasks required to review and distribute information. Incorporating a context-based, rather than a message-based approach, information synchronization and management can be formally automated allowing warriors (especially those at the fighting echelons) to concentrate on mission execution rather than on complex computer operations. Automated collaboration of mission planning and monitoring of plan execution can continue at all levels and in real time.

3.3.2 Information Management and Distribution Overview

3.3.2.1 Goals and Timeframes. Development of the required warfighter capabilities for Information Management and Distribution necessitate development in the constituent areas of Distributed Environments, Information Services Management and Assured Information Services. These technology efforts will provide the warfighter with the ability to: (1) access mission-critical data from any location on the globe in a location transparent manner, (2) collaborate on mission plans at all levels and monitor execution in real-time, (3) assess mission plans through rehearsal using synthetic environments, (4) assure continuation of mission critical functions and survive loss of resources by dynamically reconfiguring where functions are executed and how information flows, (5) provide reachback from deployed forces to garrison and support units, (6) support interoperability among both joint and coalition forces, (7) support extension of the information backbone to highly mobile, deployed forces through the integration of mobile distributed computing nodes, and (8) maintain access control, authentication, integrity and availability of classified data in a distributed information environment accessible by users with differing clearances and needs to know. Figure III.8 below illustrates the anticipated progress. A roadmap that focuses on the linkages and key relationships associated with the corresponding DTOs is provided in Section 4.

Short-Term (97–98)	**Mid-Term** (99–01)	**Long-Term** (02+)
Demonstration of distributed computing environments built on an ATM backbone (>100 Mbps)	Internetted giga-operation hybrid computing clusters	Self-aware, reconfigurable, distributed computing environments of several hundred nodes
Demonstration of real-time distributed computing across homogeneous clusters	Integrated, fixed-site, mobile node, distributed, computing environment of >200 nodes	Hybrid, real-time/non-real-time, heterogeneous, global information system

Short-Term (97–98)	**Mid-Term** (99–01)	**Long-Term** (02+)
Demonstration of object-based multimedia database management system supporting text, graphics, imagery, video, and audio	Uniform, global service model for Open Systems Architectures	Intelligent agents for information location and integration
Demonstration and simulation of lower echelon initial digital information architecture	Experimentation and demonstration of command-level information management, distribution and database capabilities	Interoperability of Joint forces using common information management and distribution with capability to access, share and protect critical information
Fault recovery mechanisms for real-time heterogeneous clusters	Fault recovery mechanisms in hybrid real-time and non real-time distributed computing environment	System adaptivity based on predictive mechanisms for resource allocation and fault avoidance
Dynamically reconfigurable clusters based on static performance policy	Intelligent agent based reconfiguration using user definable performance policy	Self learning adaptivity using static and dynamic optimizing policies
Secure guards, firewalls, intrusion detection systems at B3 level of trust	MLS distributed computing clusters at B3 level of trust	MLS object-oriented global information system with integrity and assured service

Figure III.8. Information Management and Distribution Goals

3.3.2.2 Major Technical Challenges. The critical technical challenges fall into the areas associated with the infrastructure for the Distributed Environments, mechanisms to support Information Services Management which reside within the distributed environment, and the ability to deploy Assured Information Services. In the Distributed Environments infrastructure area the critical technical challenges are (1) scalability to several thousand nodes and schedulability of time critical operations which are physically dispersed across large geographic areas, (2) varied user populations and applications, (3) multiple processor types, (4) capabilities and configurations, and (5) integration of both real-time and non real-time operating environments within the same overall system. An important issue is compatibility with emerging commercial system standards and heterogeneous computing bases while retaining DoD's desired operational capabilities. (DoD's needs are not always within commercial industry perceptions of requirements and/or priorities.).

To provide the necessary Information Services Management within the distributed environment requires the development of mechanisms for managing all types of data both on individual hosts as well as across the distributed environment. To attain this capability the critical technical challenges to be met include: (1) developing data models and storage and retrieval architectures capable of handling all modalities of data in a seamless way, (2) merging and synchronizing time-dependent and non-time-dependent data, (3) developing intelligent agents capable of autonomously navigating complex database structures and extracting information for a user, (4) developing natural language and other non parametric interfaces to support "intuitive" access and retrieval of data from the database management systems (DBMSs), (5) developing adaptive information distribution techniques based upon context based as opposed to message based distribution, (6) using the information context for smart distribution over low bandwidth communications in order to selectively control the quantity of information exchanged, (7) providing capability to respond to complete information exchange failures, and (8) scaling these information distribution techniques to large systems of communications nodes.

The key to developing Assured Information Services is adaptivity within the distributed environment to allow dynamic response to varying loads of crisis management or system failure, and protection of the information within the system from attack or compromise. The critical technical challenges include: (1) security mechanisms for multi-clustered, real-time heterogeneous distributed environments, (2)

adaptivity mechanisms which support the selective application of fault tolerance and fault avoidance strategies, (3) reconfiguration mechanisms to support graceful degradation, (4) replication mechanisms to insure the consistency of information, (5) intelligent resource managers to dynamically respond to crisis overloads, and (6) system architectures that permit the secure use of Commercial Off-the-Shelf (COTS) computers, software, and networks.

3.3.2.3 Related Federal and Private Sector Efforts. In many ways the information environments for the industrial, commercial, and financial communities mirror the military information environment. As a result there are leveragable development activities in the commercial sector addressing many of the same technical issues as the military. Global corporations and financial institutions have the need for global data access. Their multi-national status requires support for heterogeneity. Movement of global markets requires very rapid response to change and guaranteed availability. This creates the need for similar distributed information environments which provide location transparent access to globally distributed data. Initiatives such as the Object Management Group Common Object Request Broker Architecture, and the Open Software Foundation Distributed Computing Environment are providing commercial standards for distributed information environments which will guide the evolution of commercial product lines. They will also have a major impact on future military systems which will be primarily COTS based. The need to protect proprietary information and financial data demands information system security. Here the commercial sector has capitalized on DoD investment in MLS and has developed commercial products for secure operating systems, secure database management systems, intrusion detection systems and secure system design tools. Several federal and private organizations are pursuing efforts for assured information services. Both the National Security Agency (NSA) and National Institute of Standards and Technology (NIST) continue to be leaders in the development of information systems security mechanisms. The National Aeronautics and Space Administration (NASA) and the Department of Energy (DOE) did pioneering work in the areas of fault tolerance and high assurance systems. A number of universities under DoD, National Science Foundation (NSF) and private sponsorship have done extensive work in fault tolerance and system integrity.

3.3.3 S&T Investment Strategy

3.3.3.1 Technology Demonstrations

3.3.3.1.1 Distributed Air Operations Center Prototype. Demonstrate the application of distributed computing and distributed database management tools and systems to operational requirements of the Air Operations Center (AOC) that performs force level tactical air planning. The prototype will demonstrate how the functions of the air operations center can be physically dispersed over a local or wide area and still retain the integrated functionality of collocation, as well as uniform accessibility to all required databases. This demonstration contributes to the fulfillment of DTO IS15.

3.3.3.1.2 Portable Command and Control for the Joint Task Force Demonstration. Demonstrate a supportable, global grid-based, C4I software technology base that will provide distributed generation, analysis, rehearsal, and execution of Joint strike plans and crisis actions plans in realistic JTF exercises. It will provide a JTF

Commander access to multiple systems and decision aids to deliver information when and where it is needed to support operations. The near-term focus will be on demonstration of dual use technology that will support identified C-in-C requirements for battlefield preparation and enhance sensor to shooter connectivity. When successful , this demonstration completes DTO IS16.

3.3.3.1.3 Survivable Distributed Information Environment. Demonstrate the capability of a distributed computing system composed of inter-netted local clusters of computers to operate successfully under stress by gracefully degrading rather than failing. The goal is to provide a level of continuing mission support in the presence of sporadic and overlapping faults or anomalous behavior episodes. This capability will include dynamic repositioning of both processes and data to the remaining computational elements to provide continued mission execution. This demonstration contributes to the fulfillment of DTO IS18.

3.3.3.2 Technology Development. In the Distributed Environments technology effort, development is focused on: (1) real-time heterogeneous distributed computing environments, (2) distributed computing over high bandwidth global grids, (3) distributed computing over low bandwidth radio frequency (RF) communications, (4) distributed, object-oriented, multimedia database management, (5) optimal tasking assignment to distributed resources, (6) interoperability among distributed, federated database management systems, and (7) scalability of COTS products to very large scale DoD configurations

In the Information Services Management area , development needs to focus on: (1) adaptive resource management paradigms which allow dynamic reallocation of tasks to computing resources, (2) mechanisms to automatically control information exchange among nodes to limit the quantity of data based upon the context of the application and available communications bandwidth, (3) mediators to assist in the acquisition of information from multiple sources within the distributed information environment, and (4) integration of both real-time and non real-time control mechanisms within a single distributed environment.

In the attainment of Assured Information Services development is focusing on: (1) extension of security mechanisms in the composeability of COTS products to meet DoD needs, (2) development of adaptive security mechanisms which accommodate resource modifications in resource sets without violating security policy, (3) adaptive fault tolerance and avoidance mechanisms, (4) intelligent agents to dynamically respond to intermittent failures by reconfiguring the computing resource set, and (5) integrity mechanisms to assure the validity and consistency of information in the global environment.

3.3.3.3 Basic Research. There are numerous areas where basic research is being directed at the fundamental science problems of this subarea. These include:

- Active database strategies
- Transaction-oriented protocols
- Data abstractions of military concepts
- Deductive database structures
- Promiscuous data replication mechanisms
- Formal verification tools

- Real-time operating system schedulers
- Object data models
- Fault tolerance mechanisms
- Dynamic replication mechanisms

3.4 Seamless Communications

3.4.1 Warfighter Needs

Seamless Communications facilitates several of the warfighters needs and capabilities, to include Information Dominance, Information Warfare, as well as real-time Logistics Control, MOUT, in essence, all twelve Joint Warfighter needs. Communications is the mechanism to achieve secure, reliable, timely, survivable, command and control and superior battlefield knowledge. This subarea addresses technologies needed by the warfighter to obtain effective access to, and utilization of, global uninterrupted communications services. Seamless communications connotes assured, user-transparent, secure connectivity between globally-dispersed sanctuary locations and positions in theater—down to the lowest echelon foot soldier or marine, and to each ship and aircraft. This connectivity will be accomplished using a combination of U.S. Government, foreign government, commercial infrastructures, and military surface- and space-based radio frequency (RF) networks. A range of transmission media, bandwidths, signal specifications or standards, and protocols will be accommodated automatically by the networks. Voice and all types of data (e.g., text, graphics, imagery, and video) will be handled within a uniform, information transport infrastructure. These technologies will provide the commander with high capacity, flexible, tactical communications to serve all categories of users (including mobile) and satisfy the need for high-confidence communications with anyone regardless of system limitations throughout all phases of the battle.

3.4.2 Seamless Communications Overview

3.4.2.1 Goals and Timeframes. The goal is an affordable, survivable, self-managing, MLS communications system that provides the warfighter with user-transparent connectivity for voice and command, control, and intelligence (C2I) systems data over the entire combat/garrison operational continuum. The system must fully support wide-and narrow-band OTM C2I data/voice interconnections throughout a land battle zone at least 100 kilometers (km) deep and provide robust and seamless connectivity between ground, air, and naval elements of the Coalition combat force dispersed over distances up to 200 km. Achieving this goal will require significant enhancement of tactical communications systems, development of automated, seamless, interfaces between tactical systems, and between tactical and global communications systems; the development of sophisticated new radio and antenna systems for the airborne and ground, OTM portion of the warfighting force; the evolution of theater/global broadcast systems as an integral element of seamless communications, and the development of artificial intelligence tools for network planning, engineering, management, and operations. Specific technical objectives, approaches, and development time frames are defined for each of the five communications technology effort areas detailed in later paragraphs in this DTAP. General, time-phased goals that represent the

collective effort for seamless communications are provided in this paragraph. The figure below summarizes anticipated progress. A roadmap that focuses on the linkages and key relationships associated with the corresponding DTOs is provided in paragraph 4.

Short Term (97–98)	**Mid-Term** (99–01)	**Long-Term** (02+)
Integrated, low-rate voice, data, and video; independent wideband voice and data services	Low-rate interactive applications over tactical internet, extensive TCP/UDP/IP, 10 percent ATM utilization	Collaborative, wideband multimedia applications over tactical communications, megabits to the warfighter, more than 50 percent ATM Utilization
Separate circuit-/packet-/message-switched networks, tactical Internet with IP	Integrated message and data networks; mobile multicast IP fielded, wireless ATM	Tactical narrowband and broadband ISDNs
2 Mbps LOS trunk radios	45 Mbps LOS trunk radios, stationary operation	155 Mbps trunks OTM
2.4 kbps UHF SATCOM, 16 kbps SHF DSCS, No DBS	23 Mbps GBS, high data-rate spot beam coverage	GBS constellation, high data-rate spot beam and medium data-rate global coverage
Single-channel radios with limited programmability	Programmable, simultaneous RF interoperability, bridging four bands, many waveforms	Smart radio functions, auto-selection of bands, waveforms, jam resistance, LPI/D, EMI/RFI management
Limited network management capability; Lack of environmental effects prediction for C3 disruption or distortions	Semi-autonomous network management with commercial interworking	Self-healing networks with seamless, commercial interworking

Figure III.9. Seamless Communications Goals

3.4.2.2 Major Technical Challenges. Major technical challenges in this area include: (1) communications equipment interoperability in multi-vendor, multi-network, Joint/Combined force, and commercial environments; (2) framing protocol for tactical asynchronous transfer mode (ATM) links; (3) protocols for high data-rate subscriber loops subject to sporadic disturbances (e.g., Narrowband Integrated Services Digital Network [N-ISDN] and broadband ISDN [B-ISDN] loops supporting OTM airborne/surface/subsurface vehicles), (4) forward error correction for tactical ATM, (5) building a fully Internet-compliant, tactical packet network using legacy radios such as Single-Channel Ground and Airborne Radio System (SINCGARS), (6) integration of data and voice over low bit-rate links, (7) heavy multipath and deep fade effects, (8) security, (9) the development of network management and control protocols that can withstand the onset of federated and non-federated jamming attacks, (10) increases in transmit efficiency, jam resistance and (11) development of conformal arrays for airborne and OTM antenna applications.

3.4.2.3 Related Federal and Private Sector Efforts. Extensive research that supports the goals of this subarea is being conducted by the telecommunications industry. The military is leveraging literally billions of dollars of commercial investments in achieving its objectives by active participation in standards bodies, promotion of commercial development, and appropriate DoD-specific research.

3.4.3 S&T Investment Strategy

3.4.3.1 Technology Demonstrations

3.4.3.1.1 Data/Voice Integration (DVI) ATD (Navy). This effort will demonstrate the technology to provide integrated communication services in low data-rate tactical communications systems using common hardware and networks. The effort

will demonstrate sufficiently robust results to allow nearly direct industrial production of deployable systems. This effort is necessary because commercial solutions for integrated communication services do not work well in tactical networks where link data rates are as low as 2,400 bps and comparatively high data-error rates subject to many variables.

3.4.3.1.2 Digital Battlefield Communications ATD (Army). The Digital Battlefield Communications (DBC) ATD will exploit emerging commercial communications technologies to support multimedia communications in the highly mobile dynamic battlefield environment. These applications will require advances in communications bandwidth and extensions in "untethered" technology to provide the global reach expected by the warfighter of the 21st century. These new services, leverage services introduced to the commercial world and will supplement some and replace other legacy communications systems. The replaced legacy systems are those unable to keep pace with the military's rapidly increasing demand for communications capacity and global reach in support of split-based operations on a worldwide scale.

The Army will evolve an integrated communications infrastructure which utilizes commercial standards and protocols to achieve seamless global interoperability. This ATD began in 1995 and introduced a wideband packet radio called the Surrogate Digital Radio. This radio was procured to add additional capacity to the Tactical Internet in TFXXI. Commercial ATM technology will be integrated into Area Common User Systems (ACUS) such as the Army's Mobile Subscriber Equipment (MSE) to provide "bandwidth on demand" to support multimedia information requirements of the 2nd Armored Division (2 AD) in preparation for thorough warfighter evaluation in TFXXI. Continued laboratory experimentation by the Services will be supported using DISN LES interconnections. The ATD will research Direct Broadcast Satellite (DBS) technology through a series of coordinated experiments intended to develop a Global Broadcast Services (GBS) capability for the Services. Through cooperation with the other Service laboratories and with ARPA's BADD ACTD, Tri-Service experiments with GBS are planned for TFXXI and other Joint exercises. Leveraging supporting 6.2 technology base efforts in the Services, low-profile satellite communications (SATCOM) antenna technology for military Uhra High Frequency (UHF), Super High Frequency (SHF), and commercial (C, Ku, X) SATCOM bands will be evaluated in OTM applications using various tactical platforms. MLS requirements will be met by the Tactical End-to-End Encryption Device (TEED). Commercial surface-based and satellite-based Personal Communications Services (PCS) technology will also be demonstrated in TFXXI to support the need for wireless access to the ACUS.

In order to extend ATM multimedia services to forward tactical units, a Radio Access Point (RAP) will be prototyped and tested. The RAP uses a High Capacity Trunk Radio (HCTR) to provide OTM communications through a wideband airborne relay communications package to the ATM-enabled ACUS. These airborne relay packages will be developed and tested through a coordinated Tri-Service effort and will be coordinated with the DARO and ARPA for platform availability. The airborne relay package and the HCTR will be tested initially at bandwidth of 45 Mbps and then at 155 Mbps OTM and 600 Mbps for stationary use. These bandwidths are required to support ATM trunks designed for multimedia tactical battle management systems and their embedded M&S components. In its post-ATD form, each airborne relay is required to support primary and hot backup links to multiple OTM RAPs. Applicable technologies identified through the commercial communications technology program and through the

Army' battlelabs' ACT II program, will be inserted where appropriate into this ATD. The ATD will conclude in FY99 by supporting the CORPS XXI Advanced Warfighter Experiments (AWEs).

3.4.3.1.3 Information for the Warrior ATD (Air Force). This ATD's objective is to demonstrate multimedia, command and control information reachback from a deployed force to the national command authorities and stay-behind resources using a high performance multi-national, civil infrastructure. DoD and the allied Ministries of Defence, have concluded that extremely wide bandwidth communications needed to support the next generation mission planning and execution functions cannot be attained without reliance on the rapidly emerging global commercial infrastructure that includes undersea and land based fiber-optic cables and SATCOM communications. This specific demonstration will provide in-transit visibility for deployed Air Mobility Command aircraft to the Tanker-Airlift Control Center through this infrastructure. This requires: (1) the integration of Air Force legacy RF transmission equipment; (2) the rapid integration of the DoD's communications network management and control functions into the civil infrastructure to produce a virtual private military network; (3) the ability to interact cooperatively with participating allied coalition nations using this infrastructure at ATM rates, and (4) development of a process whereby DoD can rapidly tap into prepositioned entry points in the commercial infrastructure to extend connectivity hundreds of miles into an area of conflict or crisis. The goal of this demonstration is to provide the capability to use, monitor and manage assets across all these dissimilar networks and maintain interoperability within a deployed JTF. This effort will develop and demonstrate control algorithms to maintain connectivity within a dynamic deployed environment under wartime stress.

3.4.3.1.4 Secure Survivable Communications Network (SSCN) Phase II. This phase of the SSCN Program will integrate commercial ATM switching technologies into the surface, tactical wideband communication networks to support the multimedia information needs of deployed elements of the Air Combat Command such as the Air Operations Center (AOC). A fieldable package will be developed to investigate and resolve the technical issues associated with integrating ATM into the typical environment of tactical transmission systems. The driving motivation is to eliminate the duplication in current network deployments and improve the warfighters' capability to easily manage the scarce bandwidth.

3.4.3.1.5 Speakeasy. Speakeasy is a Joint Service R&D program sponsored by the RL, CECOM, and ARPA. Speakeasy is planned to be the services' next generation tactical radio. More than "just a radio," Speakeasy will be a Modular, Multifunction Information Transfer System (MMITS) with application outside the DoD and military. Speakeasy will offer federal and civil agencies the opportunity to gain wide interoperability, flexibility through re-programmability, and economical advantage through a system wherein vendors of various products compete at the module level to provide required capability. Speakeasy is an attempt to create the "PC" of the radio world. The MMITS PC/Workstation, holds potential for many vendors, not just *radio* manufacturers! Memory, signal processing, software, test and instrumentation, routing/networking, media processing, I/O interfaces, vocoders, programmable filters, encoding/decoding, RF engineering, and many, many more technical disciplines have a part to play in such an Information Transfer System.

The Speakeasy Phase II (6.3a) R&D program is developing the architecture for a six-channel (four programmable channels, one Global Positioning System [GPS] receive-only channel, one commercial cellular phone channel) multiband, multimode, radio. It will result in six advanced development models (ADMs) available in the late FY99 time frame. These Speakeasy ADMs are being designed with a Peripheral Component Interface (PCI) bus backplane and using Personal Computer Memory Card International Association (PCMCIA)-format modules. The Speakeasy program employs a model-year build-and-test strategy that will give us prototypes with increasing capability starting with a year one model in late 1996, followed by a model in late FY97, and another in late FY98. The final model will be available at the completion of the contract in FY99. Using this strategy, the Speakeasy program hopes to get feedback from users to ensure that the final units available in late FY99 are near-production ready. The final units are expected to be approximately 0.4 cubic feet in size, weigh 30 pounds or less, draw no more than 60 watts and be capable of being ruggedized for use in most military applications.

The Speakeasy radios will be capable of simultaneously operating over 4 channels, in bands anywhere in the continuous 2 MHz to 2 GHz range, employing waveforms that can be either instantly selected from memory, or downloaded from floppy disk as needed, or reprogrammed over the air. The reprogrammable nature of Speakeasy will allow users to load any legacy or future waveform software. The following waveforms are being implemented: HF; HF Modem; SINCGARS; HQ I&II; UHF SATCOM (and Demand Assignment Multiple Access [DAMA]); commercial (AMPS) cellular telephone (not part of the four programmable channels); air traffic control and civil aviation waveforms (VHF bands); a ~2 Mbps wireless packet waveform; GPS-receive capability (not part of the four programmable channels); a Low Probability of Intercept/Detection (LPI/D) waveform and the Enhanced Position Location Reporting System (EPLRS) waveforms.

3.4.3.1.6 Technology Reinvestment Project (TRP). Under the ARPA TRP (Dual-Use Applications) six projects are being initiated in FY96 in the area of digital wireless communications and networking systems. The projects are: Advanced Communications Engine; Defense Applications for a Multiple Path Beyond Line of Sight Communications Network; Digital Wireless Communications and Networking Systems Program; High-Speed Digital Wireless Battlefield Network; Miniature Filters for Wireless Networks; and a Government/industry Digital Wireless Testbed. These projects directly complement efforts on going in the Services and are being executed by the Service laboratories and centers.

3.4.3.1.7 Global Mobile Information Systems (GloMo). ARPA initiated the GloMo program in 1995 to develop and demonstrate technologies that address the continuing advances in high speed communication, signal processing, and miniaturization which in turn are opening up new opportunities for advancing the state of the art in mobile, wireless, multimedia information systems. The program supports a number of projects at various organizations ranging from concept development to prototype demonstration. The program results will be integrated into on-going development programs in the Services.

3.4.3.2 Technology Development. The Services are jointly developing feeder technology to enable the conduct of 6.3A technology demonstrations and ATDs discussed above. The design of new waveforms is being pursued to provide low

probability of intercept capabilities for both surface and airborne applications. A Joint program is developing HCTR technology for wide bandwidth, point-to-point and OTM operations. To support a worldwide reachback capability for a deployed Joint force, the Services are developing small, rapidly deployable SATCOM ground station technology, data compression techniques, techniques for assuring seamless connectivity by incorporating commercial standards such as ATM, and when necessary, developing common standards such as DAMA. To enable rapid information access by OTM surface, subsurface, and airborne vehicles, all Services are working jointly in the area of optical phased array antennas for SATCOM and air-to-surface use. Army, Navy, and Air Force 6.2 project lines are integrating and evaluating commercial high speed network technology and protocols such as synchronous optical network (SONET), IPng, and ATM for performance in tactical applications. The overriding goal is the seamless interconnection of heterogeneous tactical communications systems utilizing, to the maximum extent possible, commercial communications standards and protocols. A driving motivation is to provide the deployed forces with the same communication services that they used as part of their training in garrison. Participation in various commercial and industrial fora ensures current knowledge and immersion of military laboratory personnel in emerging commercial market standards, and maximizes the chances to influence the development path of commercial products. Tactical Multinet Gateways to be fielded by the Army in TFXXI evolved by modification and enhancement of COTS routing products, allowing ATM and non ATM-based networks to seamlessly exchange multimedia applications data. Hierarchical video routing will be investigated to automatically route limited resolution battlefield imagery to users with constrained bandwidth while, at the same time, allowing users with adequate bandwidth full resolution video services.

A long term focus of the technology base will be to provide dynamic and fault tolerant protocol functionality to enhance battlefield survivability and improve operations OTM. Dynamic network reconfiguration without user intervention will be required at all levels. Broadcast services over ATM, hierarchical video routing, and mobile, multicast Internet Protocols (IPs) will be developed for integration into the Army's DBC ATD, the Navy's Tactical Internetworking Joint ATD for Littoral and Expeditionary Warfare and the Air Force's Information for the Warrior Program. In later years, protocol enhancements for large networks will be evaluated for application to the next generation Joint military communications architecture. Lastly, all Services are actively participating in the DISA/ARPA Joint Program Initiative called the LES that provides wideband connectivity among all participants. All Services will shortly be interconnected via the LES infrastructure and will be able to conduct joint experiments and share developments in a way never before possible.

3.4.3.3 Basic Research. The Services support a broad spectrum of basic research topics in this area including:

- Network-based simulation
- LPI/D waveform design
- Quality-of-service-based protocols for mobile environments
- Multi-tiered network structures
- Dynamically adapting protocols
- Multi-dimensional routing functions
- Metrics for network assessment and evaluation

The US Army Research Laboratory (ARL), in coordination with CECOM and as part of the IS&T subpanel, has initiated a broad 6.1 funded research program to explore technical solutions in the areas of wireless digital battlefield communications, tactical and strategic interoperability, and information distribution for multimedia services. This program, known as the Federated Laboratories, is being executed through a multi-year collaborative partnership among the Army, academic institutions, and industry. These efforts directly complement and in many cases feed the DBC ATD and the Tactical Internetworking ATD.

3.5 Computing And Software Technology

3.5.1 Warfighter Needs

Computing and Software Technologies (as is the case with Modeling and Simulation) are significantly important to all Joint Warfighting Needs and Capabilities. In the information age, warfighting is significantly influenced by the speed, accuracy, and quality of information provided for applications such as C4I, precision weapons, logistics support, and readiness support. In such applications, a few well-trained humans, augmented or assisted by high performance, automated systems, can outperform dozens, hundreds, and sometimes, thousands of unautomated or poorly automated well-trained personnel. The computing foundations developed by this subarea provide the advantage in any conflict or operation permitting early, decisive victory or rapid non-combat response in operations other than war with minimal cost in assets and human life. Advancements in software and software development productivity support both the capability and the affordability of new and upgraded defense systems. Computing and software technologies such as software re-engineering, software reuse, and software acquisition strategy have significant impact on weapon systems' upgrades, product improvements, and system performance advancements. Pervasive throughout all technology areas, and as important, are embedded high performance computing, embedded software and system engineering, knowledge-base design, advanced hardware/software system architecture technology, information presentation and interaction, and intelligent information technology.

3.5.2 Computing And Software Technology Overview

3.5.2.1 Goals and Timeframes. For ease of portrayal and discussion, the four related but distinct technical aspects that make up this subarea are considered separately. These four aspects are:

- Information Presentation and Interaction
- Machine Intelligence
- Computing Systems
- System Design and Evolution

Specific computing and software goals and time frames are shown in the Figure III.10. A roadmap that focuses on the linkages and key relationships associated with the corresponding DTOs is provided in Section 4.

	Short Term (97–98)	**Mid Term** (99–01)	**Long Term** (02+)
Information Presentation and Interaction	Heavily tethered, helmet-mounted 3–D displays	Single user immersible VR with pre-calculated displays, tether-free 3–D displays	Multiple user immersible VR, real-time displays
	Limited (10 k word), speaker-dependent, vocabularies	Medium(50 k word), speaker-independent vocabularies	Large, speaker-independent vocabularies
	Single user, single discipline	Multiple user, single discipline collaboration	Multiple user, multiple discipline collaboration
Machine Intelligence	Real-time planning for intelligent devices	Real-time adaptation of intelligent devices to changing situations	Plan creation and execution among cooperating intelligent robots
	Autonomous devices operating independently on single tasks	Team tactics demonstrated for autonomous multi-agent behavior	Self-initiated plan creation and execution among cooperating intelligent robots
	Unintegrated and unfiltered data searches in Cyberspace	Filtered information searches by intelligent agents in Cyberspace	Filtered and integrated responses to information queries in Cyberspace
Computing Systems	100 GFLOP/cubic foot for militarized HPC	500 GFLOP/cubic foot.	T-FLOP/cubic foot
	10–20 Percent efficiency on MPP	50 Percent overall efficiency on MPP	
	Max 300 GFLOP sustained	Scalable Designs to 10 T-FLOPS	Scalable Designs to 100 T-FLOPS
	Baseline Performance on ATR	10X Baseline on ATR	
System Design and Evolution	Cost/quality/performance certification process for COTS or other reusable components	Commercial vendor's adhere to cost/quality/certification process	Certification of self-learning/adaptive systems demonstrated
	No criteria for applications architecture evaluation/comparison	Criteria for non-real-time algorithmic architectures in place	Criteria for real-time and knowledge-based architectures in place
	Ad-hoc architectures approach	Standards for architectures based on object orientation demonstration	Standard architectures for real-time, secure and knowledge-based software in place
	Developed component by component with extensive use of COTS/GOTS	Domain specific development through specification process only	Warfighter modifiable systems in place

Figure III.10. Computing and Software Technology Goals

3.5.2.2 Major Technical Challenges.

3.5.2.2.1 Information Presentation and Interaction. The overall goal is to allow the humans in the loop to exploit all information relevant to their individual tasks, without reaching "information overload" and respond in a timely manner. The approach is to make *maximum effective* use of all the human senses and intellect to perform this task in as natural appearing an environment as possible. One technical challenge is to build and incorporate affordable, high-resolution large 3–D displays into systems to depict an accurate picture of the situation to the visual senses and enhance those system interfaces with natural language and gesture I/O. A second technical challenge is to provide a truly interactive, virtual reality depiction of the situation with human "immersion." The depiction will then be further enhanced by removing artificial tethers such as helmet mounted displays and data gloves, providing real-time updates to the depiction, and allowing the immersion of multiple humans at the same time. Some aids to visualization rely on sensing the location and orientation of the participant. Participant location and orientation are used to adjust the presented visual scene. Inaccurate or delayed tracking can induce virtual reality sickness (akin to motion sickness). Therefore,

a third challenge is improvements in measurement resolution, accuracy, and responsiveness needed to promote improvements in aids to visualization.

3.5.2.2.2 Machine Intelligence. The overall goal is to provide techniques for automated reasoning to advance the capabilities of single and multiple autonomous robotic systems and intelligent aids to human decision making. Deep challenges remain in integrating reactive and reflective planning, achieving control in unstructured, real-time environments; automating cooperation among multiple intelligent systems; using simulated devices and environments to debug and optimize complex control software; and exploiting varieties of machine learning methods in conjunction with those simulations. Meeting these challenges contributes to the ability for autonomous and semi-autonomous vehicles and weapons platforms to operate undersea, on the ground, or in the air, as well as allowing intelligent software agents to better aid in decision making and efficient information searches in Cyberspace.

3.5.2.2.3 Computing Systems. For the technologies involved with computing systems, the overall goals are to overcome the inevitable (and already present in some applications) limitations in computational throughput, as well as the cost, power, size, and weight requirements for single or small numbers of networked computers. These requirements and limitations impact weapons systems, simulators, and engineering support systems. The technical challenges are to cut the costs and size of giga-and tera-floating point operation (FLOP) computers so they might fit into a weapons package, to make efficient use of parallel and massively parallel computing assets, and to design systems that will allow easier, and hopefully, very low cost transition to the future commercial advancements in both hardware and software to achieve truly architecture-independent, high-performance computing.

3.5.2.2.4 System Design and Evolution. In the area of System Design and Evolution, the overall goal is to reduce the time and cost of building, deploying, and modifying software-intensive systems while increasing the overall quality in terms such as residual errors, reusability, and integrity. A subgoal is to allow the warfighter to program the system he needs for his specific battle environment. The technical challenges are to develop and/or automate techniques for forward system engineering approaches and provide tools which have a systematic, holistic approach to design and information management across the system life-cycle, as well as for the activities associated with the reengineering and reverse engineering of legacy systems for modernization or reuse.

3.5.2.3 Related Federal and Private Sector Efforts

3.5.2.3.1 For Information Presentation and Interaction, major related efforts include NASA work on human-computer interfaces for the Space Shuttle, the proposed NASA Space Station and ground-control workstations. and private sector applications in the business domain. Private sector participants include Apple Corporation, Microsoft, Sun Microsystems, IBM, Xerox PARC, and AT&T. Universities having substantial programs in this area, funded through domestic and international customers include Carnegie Mellon, Stanford, the University of Southern California, Georgia Institute of Technology, Massachusetts Institute of Technology, Virginia Polytechnic Institute, and the University of Arizona. The university focus is almost solely on commercial applications of novel interface technologies, virtual reality, and intelligent user interfaces.

3.5.2.3.2 Machine Intelligence Research and Development, while getting the majority of its funding from DoD, is augmented with programs from NASA, dealing with expert systems and intelligent controls; DOT, dealing with applications on land and air traffic control; and the DOE, concentrating on control of industrial processes. NSF supports a broad program of basic research in robotics and intelligent systems. In addition, there are a significant number of industrial firms which have internal research and development (IR&D) projects studying related machine intelligence technology.

3.5.2.3.3 Computing Systems represents a significant part of the U. S. program in High Performance Computing and Communications (HPCC), which involves the Department of Education, NSA, DOE, the EPA, NASA, NSF, NIST, and the National Oceanic and Atmospheric Administration (NOAA). Most of the major vendors of high performance computing systems, including the workstation manufacturers Hewlett-Packard, Sun Microsystems, and Silicon Graphics are building on the scaleable computing technology developed by the programs that are part of this subarea. There are major technology efforts underway at industry/Government sponsored consortia such as MCC (Microelectronics and Computer Technology Consortium), often involving DoD sponsorship matched with significant industrial cost sharing. The TRP has also targeted some of this technology for dual-use development and defense conversion.

3.5.2.3.4 System Design and Evolution is an area of widespread national concern. The DoD R&D organizations work very closely with the industrial sector to address the challenges in this area. NSF has Government-Industry-University Cooperative Research Centers, two examples of which are the Software Engineering Research Center collocated at Purdue University and the University of Florida; and the Center for Information Management Research, collocated at Georgia Institute of Technology and the University of Arizona. The Software Productivity Consortium (SPC) in Herndon, VA gets its basic funding from about 15 major companies with a strong interest in increasing their software productivity and from the DoD. The DoD labs and the SPC have worked out or are currently working out agreements to share and expand on their successful software engineering products. By Congressional action, the National Applied Software Engineering Center has been established, due in no small part to the efforts of the Service Labs and ARPA.

3.5.3 S&T Investment Strategy

3.5.3.1 Technology Demonstrations

3.5.3.1.1 Information Presentation and Interaction is a supporting technology, and as such has no current formal technology demonstrations. However, a Technology Demonstration for Developing Speech Recognition for Future Digital Signal Processors (DSPs) in Handheld Computers was funded by the Technology Reinvestment Program (TRP) and demonstrated a family of continuous speech recognition capabilities ranging from small vocabulary for command and control to a large vocabulary for dictation.

3.5.3.1.2 Machine Intelligence has technology demonstrations in Autonomous Vehicles and Image Understanding Architecture (IUA) Vision and covers a technology demonstration that is key to the Decision Making IS&T subarea, namely USTRANSCOM Planning Tools. The USTRANSCOM Planning Tools demonstration is aimed at developing the next generation of generic AI planning, resource allocation, and

scheduling technology. It is responsible for the capture of new AI planning capabilities in robust, application ready software tools, and the demonstration of the feasibility of their application against employment and deployment crisis action planning tasks within the context of USTRANSCOM exercises.

Autonomous Vehicles focuses on ground vehicles for phase IV of a four-phased program. This phase will integrate a reconnaissance, surveillance, and target acquisition subsystem, with a multiple vehicle mission subsystem, resulting in the robust navigation of a team of four vehicles as a screening force in support of manned vehicles. The IUA Vision Demonstration is a TRP to develop and demonstrate important image understanding (IU) products by using and enhancing existing IU software technology and COTS hardware technology in a common architecture. The result will be an architecture that will allow IU capabilities in deployed systems to improve as rapidly as the technology is delivered.

3.5.3.1.3 Computing Systems has a large technology demonstration that provides many enabling technologies for the Information Management and Distribution IS&T subarea as well as the business and combat missions of DoD. Information Infrastructure Services focuses on the Cyberspace areas of electronic transactions, information management, and transaction support services, including common authentication, authorization, and accounting services; resource registration and discovery, real-time multimedia interoperability; and adaptive computing services.

3.5.3.1.4 System Design and Evolution has two technology demonstrations. The first demonstration, Software Life Cycle Support, is intended to develop, demonstrate, and transition state-of-the-art computer system and software engineering technology that supports the complete system life cycle and improves the productivity of the process and quality of the products. Aimed primarily at the embedded world, this program has already demonstrated to Joint Surveillance Target Acquisition Radar System (JOINT STARS), the Next Generation Attack Submarine (NSSN), F–16, and other military programs as well as civil applications in air traffic control. Additional demonstrations to these organizations are planned.

The second demonstration, called the Evolutionary Design of Complex Systems (EDCS) will demonstrate the next generation of technologies, processes and development environments beyond computer-aided software engineering (CASE) and knowledge-based engineering to address the unique requirements of large-scale, complex systems with long life cycles where missions and performance requirements tend to evolve over the life of the system. The objective is to scale-up the incremental development and prototyping paradigms as a means to increase effectiveness of systems and systematically reduce risks over the entire system life cycle. Technology demonstrations will address applications software system architecture technologies to support: (1) the evolution of a system implementation, (2) a knowledge-based environment in which all aspects of a system life cycle are formalized, (3) language support for evolutionary development of software components, (4) a specification techniques for complex software architectures, (5) software systems with components written in multiple programming languages, and (6) experimental tools to support the refinement of software prototypes into production quality systems.

3.5.3.2 Technology Development. The Information Presentation and Interaction aspect of this subarea requires advancements in many technologies to achieve the goals

for optimizing human performance in the information rich combat environments of the present and future. Some of the advancements needed will be funded by the commercial sector, but in many cases, the DoD must scale up the "game oriented developments" to real-world military applications. DoD must make continue investments in: (1) real-time adaptable user interfaces, (2) crew-aiding systems, (3) intuitive multi-user interfaces, (4) real-time processing and display of solid objects, (5) locomotion control, (6) robust real-time speech recognition and understanding, (7) text processing, understanding, and multi-lingual translation, and (8) interface and interaction development tools to facilitate design and development of interfaces, human-computer dialogs, integration of human and computer control, system composition and integration, and virtual reality fidelity.

Machine Intelligence, which is most heavily influenced by DoD investment, investments in the following areas to achieve its objectives for automated reasoning and autonomous vehicles: (1) extensions and alternatives to rule-based systems, particularly CASE-based reasoning, (2) machine learning and machine vision, (3) tools for the off-line design and on-line adaptation of fielded systems, (4) hybrid (incorporating both human and computer) control strategies including behavior-based architectures and for semi-autonomous control, incorporation of the technologies covered in Information Presentation and Interaction into robotic systems, (5) real-time, autonomous planning and scheduling of tasks that can deal with temporal aspects and uncertainty, (6) integration of intelligent systems across domains, and (7) the general tools and technology to build and validate intelligent systems.

Computing Systems needs advancements in both hardware and software technologies to achieve its objectives for overcoming the DoD mission shortfalls resulting from high cost and/or computationally-bound computing systems. These listed advancements recognize the progress being made for commercial applications, and are geared to capitalize on that progress as well as the projected progress for commercial applications. The needed investment areas are: (1) real-time operating systems for high performance computing, (2) common building blocks architectures for military applications that are portable between underlying components, (3) tera-FLOP scalable embedded systems, (4) computing networks that keep up with processor performance, (5) caching models, hardware-accelerated communications and multithreaded systems to overcome latency problems, (6) architectures and commercial leveraging and packaging to overcome the still prohibitive costs per MFLOP for embedded and non-embedded systems, (7) tools, strategies, and architectures for reducing the huge gap between sustained and peak performance, (8) tools to overcome the verification gap for complex computing hardware (e.g., the Pentium bug), (9) scalable design algorithms to overcome design complexity, (10) computational prototyping and low-cost evaluation to overcome the high cost of physical prototyping of complex hardware, and (11) software engineering tools to assist in making most efficient use of parallel and massively parallel computation architectures.

The System Design and Evolution aspect needs technology advances in a number of areas to meet its goals for rapid development and delivery of low-cost, high quality software-intensive systems. There is a broad reliance on tools and techniques for improving the processes associated with the software-intensive system from conception through system retirement. These include: (1) software reengineering and reuse technologies including rationale recapture and understanding, domain analysis, respecification, architecture transformation; (2) fault-tolerance methods for critical

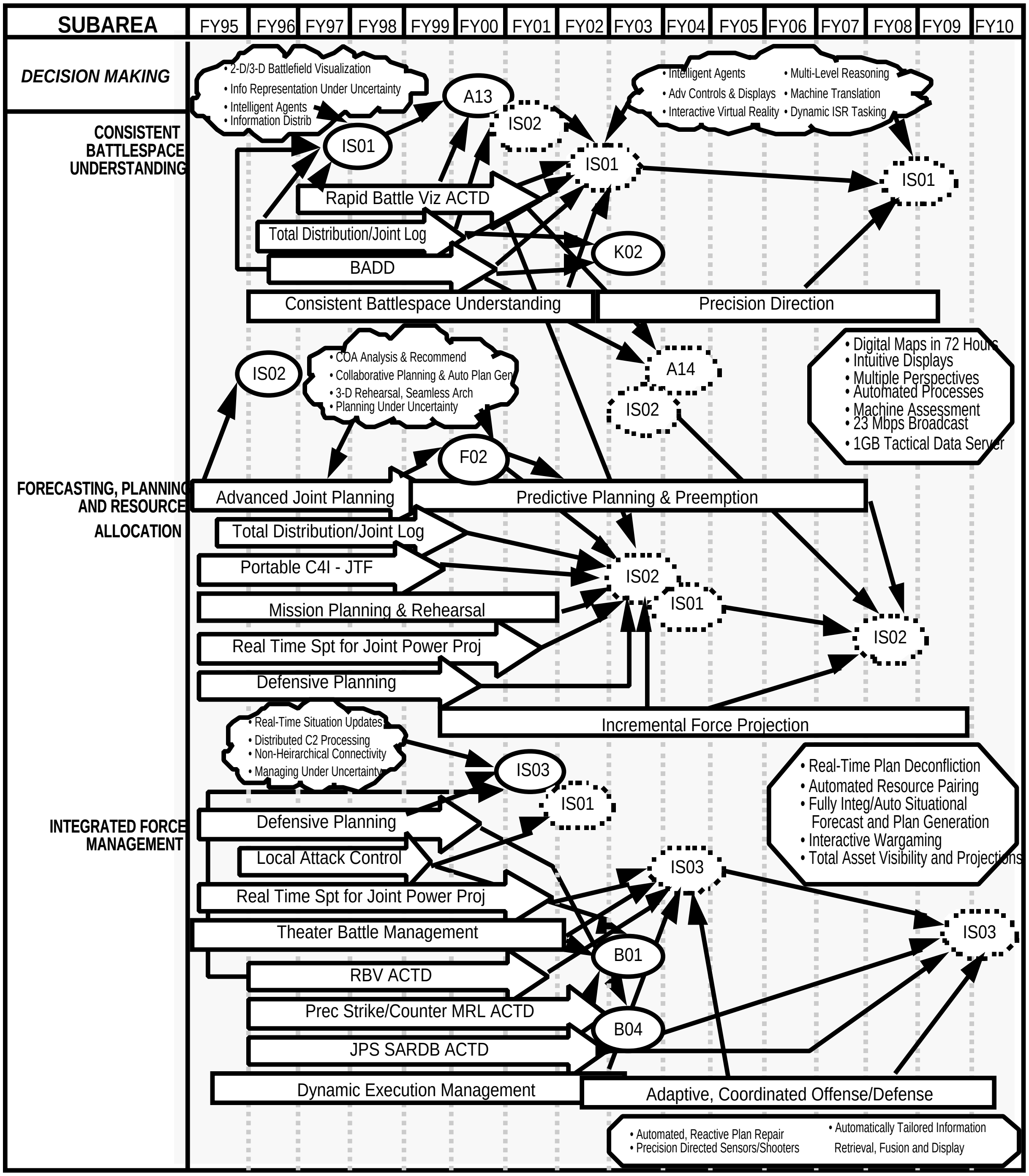
system applications; (3) system and software engineering frameworks and components including requirements analysis, real-time analysis, common design records (with tailored views for the various stakeholders in system development), constraint management, truth-maintenance, group collaboration, analysis and mining of design information, multi-media, simulation/modeling, and interoperability; (4) high-assurance techniques to support software for distributed, real-time, and heterogeneous computing architectures; (5) integrated automation tools, in some cases embodying knowledge-based technology, to assist system builders in exploring the total system design space and in synthesizing alternative system configurations including hardware, software and human processes; (6) evaluation and assessment technologies that enable uniform and consistent measurements of critical attributes throughout the system development process and support revalidation of outcomes at each level of system abstraction and step of refinement; and (7) production technology for building complex computing systems including automated capabilities to precisely specify software architectures, to analyze architectural influences on systems performance, and to facilitate composition of software systems through software module reuse.

3.5.3.3 Basic Research. In support of the above technology development program, significant investments in basic research should continue to overcome gaps in both theory and the scale of the existing theories for computing and software technologies including:

- Human computer interaction
- Human language technology
- Machine learning methods (particularly genetic algorithms)
- Planning and AI-based design
- Dynamic, very-high-level languages
- Parallel programming languages and "parallelizing" techniques
- Vision and image understanding
- Virtual Reality
- Alternative computing paradigms, such as artificial neural networks, neuro-fuzzy logic, biologically-based neural networks and hybrid digital/optical processing
- Operating system and resource mgmt.
- Formal methods for software engineering
- Software prototyping, development, and evolution
- Software architecture evaluation metrics
- Engineering of knowledge-based systems
- Software intensive system predictability for both conventional and AI-based systems
- Software understanding/rationale capturing
- High-assurance techniques

4. TECHNOLOGY AREA ROADMAP AND RESOURCES

4.1 Information Systems Technology Area Roadmaps - See Figures III.11-15



IS01 = Consistent Battlespace Understanding
IS02 = Forecasting, Planning and Resource Allocation
IS03 = Integrated Force Management
A13 = Rapid Battlefield Visualization ACTD
F02 = Advanced Joint Planning ACTD

B01 = Precision Strike Counter MRL ACTD
B04 = Joint Precision Strike SARDB
K02 = Joint Logistics ACTD
A14 = Battlefield Awareness and Data Dissemination ACTD

LEGEND

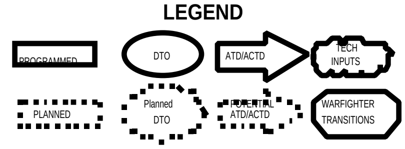


Figure III.11. Decision Making Roadmap

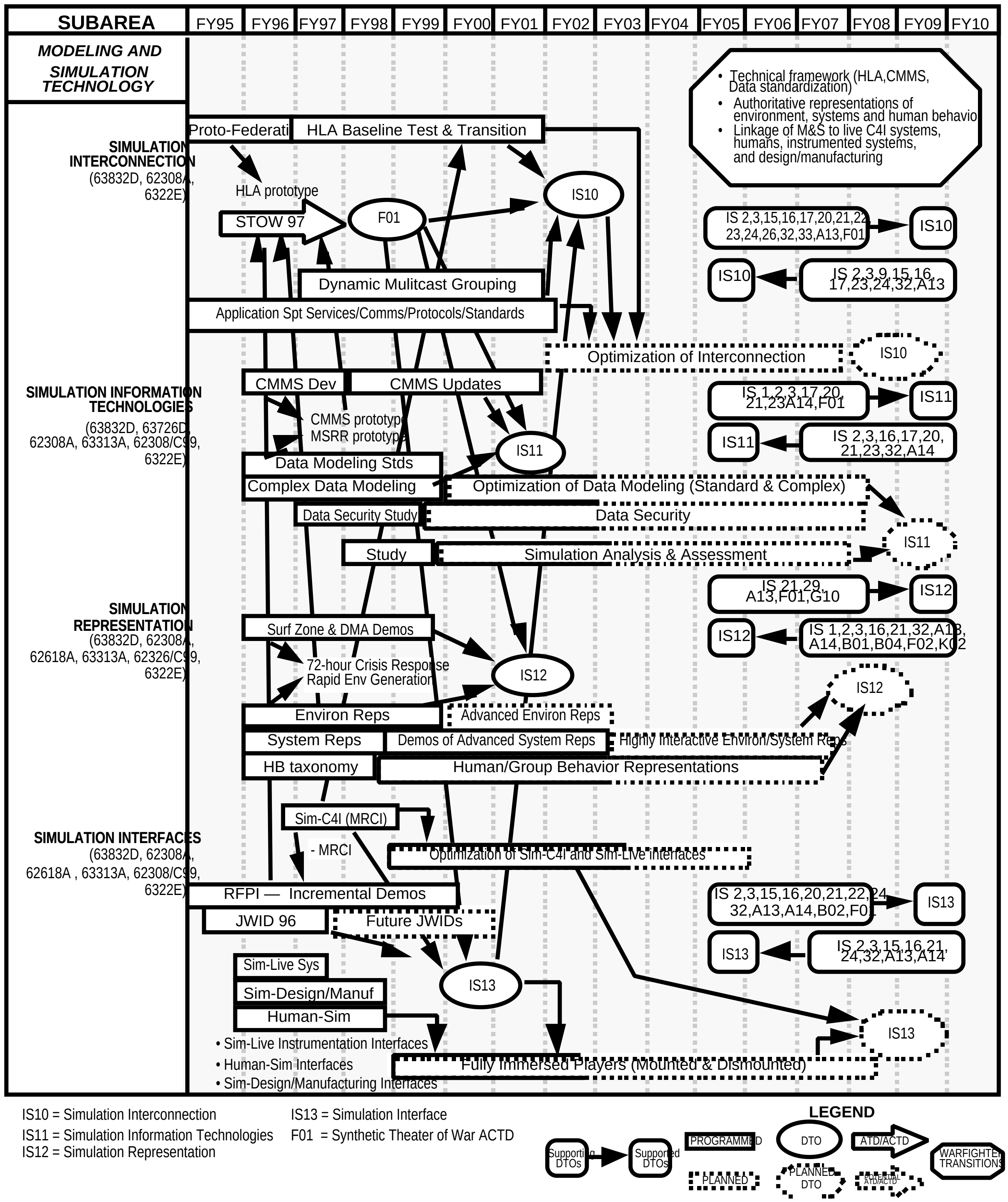


Figure III.12. Modeling and Simulation Roadmap

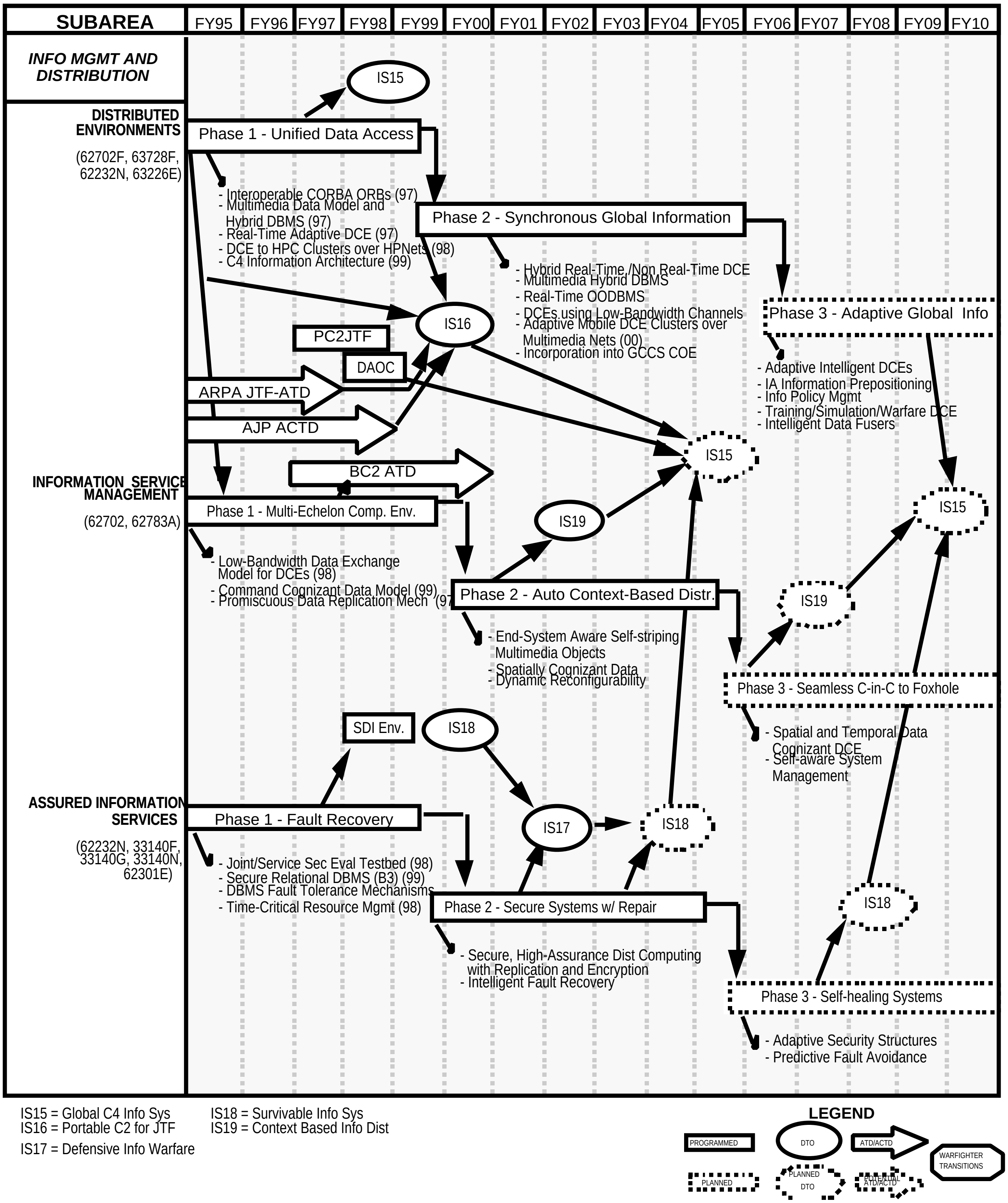


Figure III.13. Information Management and Distribution Roadmap

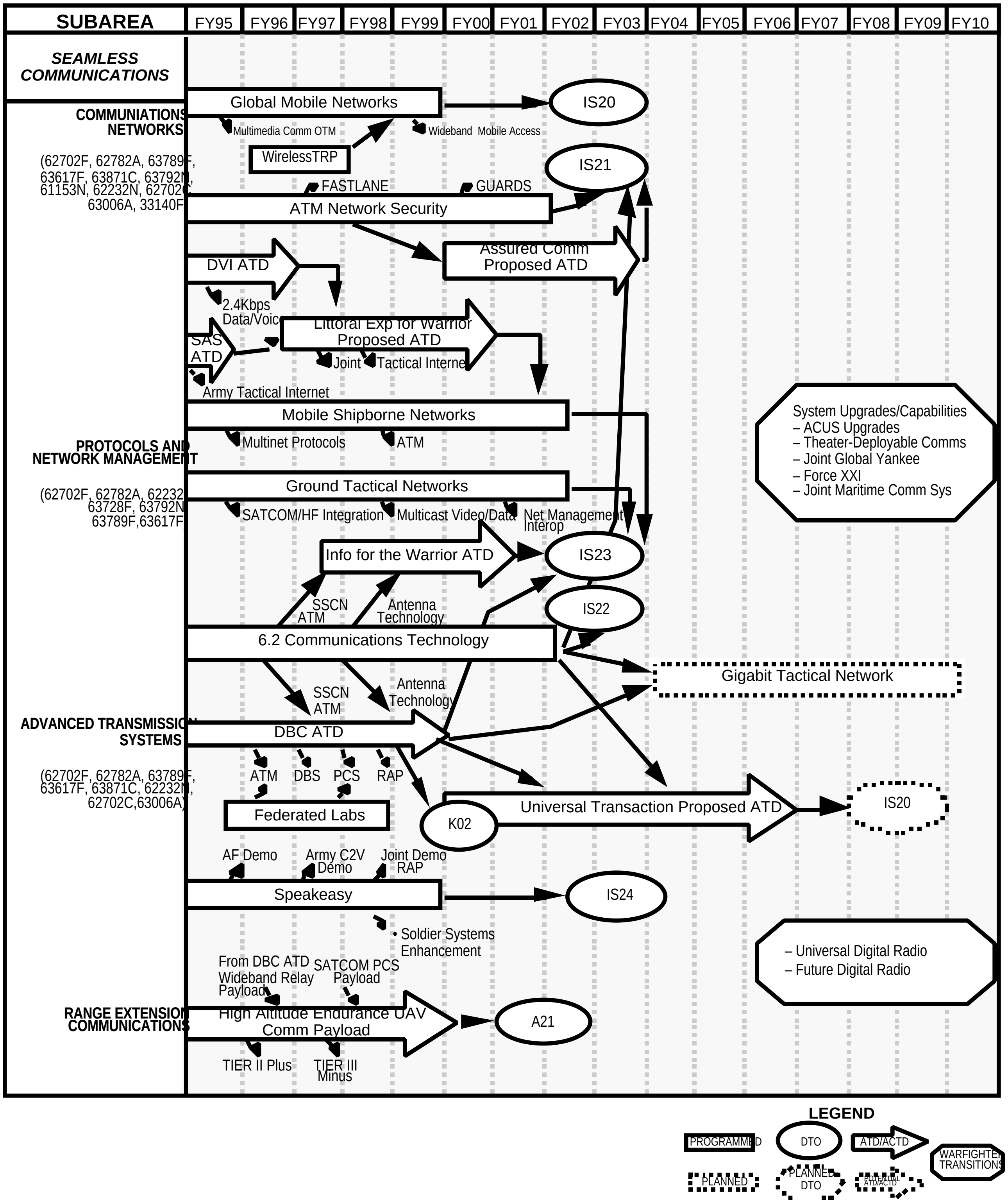


Figure III.14. Seamless Communications Roadmap

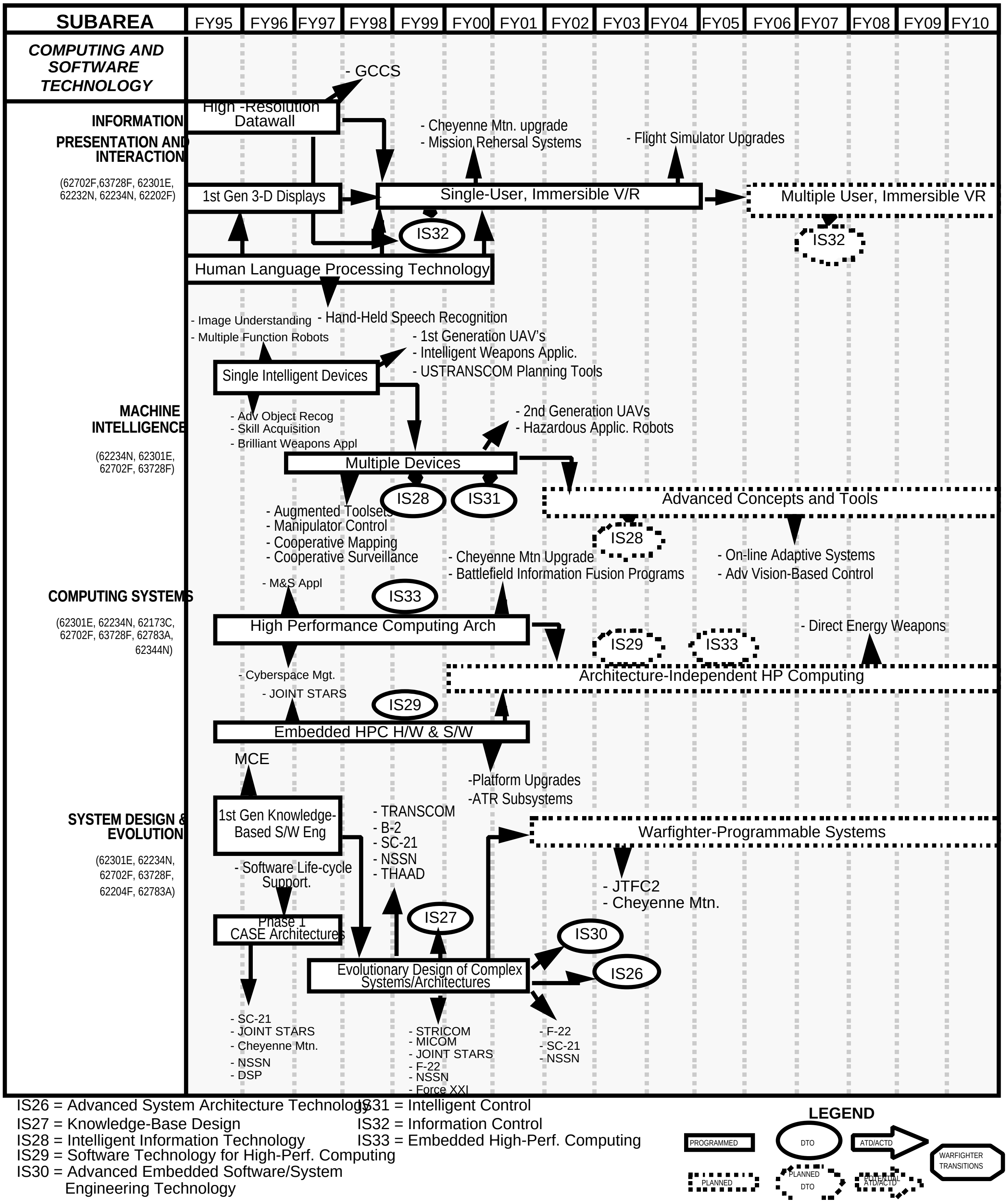


Figure III.15. Computing and Software Technology Roadmap

4.2 Information Systems and Technology Roadmap Resources ($M)

DTO	Program Element	$ in millions					
		FY1996	FY1997	FY1998	FY1999	FY2000	FY2001
IS01 Consistent Battlespace Understanding	0603772A	1.0	2.2	2.5	2.8	2.5	0
	0602782A	1.0	1.4	1.8	2.5	0	0
	0602783A	0.2	0.1	0.1	0.2	0.2	0.2
	0602232N	0.3	0.4	0.5	0.5	0.5	0.6
	0603794N	4.0	2.6	2.5	1.9	0	0
	0603270A	0.7	0.6	0.6	2.0	2.0	0
	0602270A	1.5	2.7	2.9	3.1	3.3	0
	0602702E	12.0	0.1	0.3	8.7	14.0	19.7
	0603226E	19.1	52.7	51.6	39.9	27.9	0
	DTO Total	39.8	62.8	62.8	61.6	50.4	20.5
IS02 Forecasting, Planning and Resource Allocation	0603772A	0.6	1.4	1.6	1.7	1.6	0
	0602782A	0.6	0.8	1.1	1.5	1.5	1.6
	0602702F	--	2.3	2.2	2.6	2.5	2.6
	0602783A	0.1	0.1	0.1	0.1	0.1	0.1
	0603728F	--	1.6	1.1	1.3	0.8	0.9
	0603789F	1.7	1.0	1.0	1.0	1.5	2.0
	0602232N	1.7	1.7	1.0	2.1	2.0	2.0
	0603794N	9.5	8.5	9.0	9.5	10.0	10.0
	0602702E	6.4	17.1	28.7	16.7	7.6	0
	0602301E	15.5	10.7	7.2	12.9	18.1	20.1
	DTO Total	36.1	45.2	53.0	49.4	45.7	39.3
IS03 Integrated Management	0603772A	0.8	1.6	1.9	2.1	1.9	0
	0602782A	0.7	1.1	1.3	1.9	1.9	0
	0602783A	0.2	0.1	0.1	0.1	0.1	0.2
	0602232N	0.4	0.5	0.6	0.3	0.3	0.3
	0603794N	3.0	2.0	1.9	1.4	0	0
	0602782A	2.0	3.7	0	0	0	0
	0602783A	1.2	0	0	0	0	1.0
	0602232N	2.7	0	0	1.9	3.2	4.8
	0603794N	1.1	0.1	0.1	0.9	1.3	1.5
	DTO Total	12.1	9.1	5.9	8.6	8.7	7.8
IS10 Simulation Intercon- -nection Technologies	0603832D	21.3	19.6	22.7	23.7	24.6	25.7
	0602308A	2.8	3.1	3.3	3.5	3.7	3.9
	DTO Total	24.1	22.7	26.0	27.2	28.3	29.6
IS11 Simulation Information Technologies	0603832D	19.5	14.4	13.6	13.9	14.4	15.1
	0602308A	1.6	2.3	2.8	2.9	2.6	2.7
	0603313A	0.7	0.7	0.7	0.7	0	0
	0602702E	2.2	2.2	0.1	1.1	2.1	3.0
	0603744E	5.2	0	0	0	0	0
	DTO Total	29.2	19.6	17.1	18.6	19.1	20.8

Figure III.16. Information Systems and Technology Roadmap Resources
TOTALS MAY NOT AGREE DUE TO ROUNDING

DTO	Program Element	$ in millions					
		FY1996	FY1997	FY1998	FY1999	FY2000	FY2001
IS12	0602715H	1.3	1.1	0.8	0.9	1.6	2.4
Simulation	0603832D	23.7	14.5	21.5	23.3	23.4	23.1
Representation	0602308A	1.3	1.9	2.1	2.3	2.2	2.2
Technologies	0602618A	0.3	0.4	0.5	0.5	0.3	0.4
	0603313A	2.1	1.5	0.8	0.8	0	0
	DTO Total	28.7	19.4	25.7	27.8	27.5	28.1
IS13	0603832D	8.7	9.2	9.5	9.6	9.9	10.1
Simulation Interface	0602308A	2.3	2.5	2.2	2.1	2.3	2.3
Technologies	0602618A	--	--	1.9	2.0	2.0	2.0
	0603313A	3.2	5.9	7.2	4.2	0	0
	DTO Total	14.2	17.6	20.8	17.9	14.2	14.4
IS15	0602232N	3.1	3.4	3.8	2.7	3.5	3.8
Global C4 Information	0602702F	1.5	2.9	3.2	3.3	3.7	3.9
System Infrastructure	0603728F	2.6	2.1	1.9	1.9	2.0	2.0
	0602301E	13.8	15.7	17.4	22.7	18.1	20.1
	0602702E	8.4	9.1	2.8	5.4	7.8	10.3
	0603226E	2.5	2.4	0	0	0	0
	DTO Total	31.9	35.6	29.1	36.0	35.1	40.1
IS16	0602301E	3.6	0	0	0	0	3.1
Portable C2 for the	0603226E	6.2	11.5	25.0	50.0	85.0	104.0
Joint Task Force							
	DTO Total	9.8	11.5	25.0	50.0	85.0	107.1
IS17	0303140F	7.0	5.6	6.3	6.8	7.7	7.7
Defense Information	0303140G	1.9	1.7	1.8	1.8	1.8	1.9
System Warfare	0603794N	1.0	0.9	1.0	1.5	1.0	1.0
	0602301E	7.8	15.9	23.9	22.0	11.9	11.9
	0602232N	0.9	1.2	1.3	1.6	1.6	1.6
	0303140N	0.9	1.5	1.3	1.3	0.9	0.9
	DTO Total	19.5	26.8	35.6	35.0	24.9	25.0
IS18	0603728F	0.5	0.4	0.4	0.5	0.5	0.5
Survivable Information	0603730E	10.9	13.1	10.6	10.6	11.3	13.5
Systems							
	DTO Total	11.4	13.5	11.1	11.1	11.8	14.0
IS19	0602702F	0.5	1.2	1.2	1.5	1.5	1.6
Context Based	0602783A	1.8	2.0	2.4	3.1	3.1	3.3
Command & Control	0603226E	6.9	14.0	10.4	29.4	0	0
	DTO Total	9.2	17.2	14.0	34.0	4.6	4.9

Figure III.16. Information Systems and Technology Roadmap Resources (cont.)
TOTALS MAY NOT AGREE DUE TO ROUNDING

DTO	Program Element	$ in millions					
		FY1996	FY1997	FY1998	FY1999	FY2000	FY2001
IS20	0602702F	4.2	2.2	0.7	0	0	0
Universal Transaction	0603789F	0.4	0.5	1.1	0	0	0
Communications	0603794N	1.4	1.9	2.0	2.1	2.3	2.4
	0603617F	0.2	0.4	1.1	3.1	3.2	3.3
	0603871C	0.5	1.5	1.5	1.2	0	0
	0602782A	4.3	4.1	4.3	4.7	5.4	5.5
	0602232N	3.8	4.2	2.4	2.7	2.7	2.8
	0603796N	--	7.5	6.0	4.5	0	0
	DTO Total	14.8	22.3	19.1	18.3	13.6	14.0
IS21	0603006A	0.5	0.1	0.2	0.2	0	0
Assured	0303140F	--	0.4	0.4	0.4	0	0
Communications	0602301E	15.0	17.7	21.2	27.3	31.0	21.8
	DTO Total	15.5	18.2	21.8	27.9	31.0	21.8
IS22	0602702F	0.6	1.3	3.4	3.9	3.4	1.1
Network Management	0603789F	0.4	0.5	0.8	0	1.3	2.0
	0603794N	1.8	3.2	3.4	3.6	3.7	3.7
	0602232N	0.3	0.3	0.3	0.3	0.4	0.4
	0602782A	0.4	0.4	0.4	0.4	0.4	0.4
	0603226E	7.0	9.3	9.4	8.5	8.6	8.9
	DTO Total	10.5	15.0	17.7	16.7	17.8	16.5
IS23	0602702F	4.9	5.4	6.2	7.7	8.0	11.2
Digital Warfighter	0603238F	2.0	2.3	2.4	2.6	3.1	2.8
Communications	0603253F	8.0	5.1	4.0	3.8	4.1	4.3
	0602204F	3.0	3.0	2.3	2.4	2.4	2.5
	0602782A	1.5	1.8	1.9	2.1	2.3	0
	0603006A	14.0	17.0	12.0	10.3	0	0
	0603792N	1.0	0	0	0	0	0
	0603226E	--	9.9	19.0	15.0	0	0
	0603871C	0.3	0.4	0	0	0	0
	INCA	5.1	5.3	5.3	0.3	0	0
	0602232N	2.6	2.9	3.3	3.6	3.7	3.8
	DTO Total	42.4	53.1	56.4	47.8	23.6	24.6
IS24	0602702F	2.8	4.5	3.5	2.2	2.8	2.5
Multiband, Multimode	0603789F	2.7	2.6	2.2	4.3	2.6	0
Information System	0603006A	2.4	2.8	2.9	3.4	0	0
	0603226E	11.2	5.1	0	0	0	0
	DTO Total	19.1	15.0	8.6	9.9	5.4	2.5
IS26	0602301E	65.5	48.3	52.3	49.6	71.6	92.0
Advanced System	0602712E	6.5	0.1	2.6	5.3	9.3	12.1
Architecture	0603226E	17.8	14.0	16.1	9.0	8.4	13.1
Technology	DTO Total	89.8	62.4	71.0	63.9	89.2	117.2

Figure III.16. Information Systems and Technology Roadmap Resources (cont.)
TOTALS MAY NOT AGREE DUE TO ROUNDING

DTO	Program Element	$ in millions					
		FY1996	FY1997	FY1998	FY1999	FY2000	FY2001
IS27	0602702F	1.1	2.5	3.0	3.1	3.5	3.6
Knowledge-Based	0603728F	1.8	1.3	1.3	1.3	1.8	1.8
Design	0602301E	15.3	32.1	29.7	33.3	24.8	21.6
	0602712E	6.4	8.7	2.6	5.2	9.2	12.1
	DTO Total	24.6	48.9	36.6	42.9	39.3	39.1
IS28	0602702F	0.8	2.0	2.0	2.3	2.5	2.1
Intelligent Information	0603728F	0.4	0.7	0.8	0.7	0.7	0.6
Technology	0602783A	1.1	1.0	1.1	1.1	1.2	1.2
	0602301E	41.8	47.9	44.6	45.4	55.4	59.3
	0603226E	4.6	1.0	1.6	0	0	0
	0603570E	13.6	0	0	0	0	0
	DTO Total	62.3	52.6	50.1	49.5	59.8	63.2
IS29	0602702F	0.9	2.9	1.6	1.2	1.2	1.3
Software Technology	0603728F	0.5	0.9	0.9	0.8	0.7	1.0
for High-Perfor-	0602234N	3.2	3.1	3.9	4.4	4.4	4.5
-mance Computing	0602301E	38.2	40.5	48.6	51.4	61.0	54.5
	DTO Total	42.8	47.4	55.0	57.8	67.3	61.3
IS30	0602702F	1.5	2.8	4.0	5.1	4.9	6.5
Advanced Embedded	0603728F	2.5	1.5	1.4	1.5	1.7	1.5
Software/System	0602783A	1.1	1.0	1.1	1.1	1.2	1.2
Engineering	0602234N	4.3	4.7	5.1	6.5	6.6	6.7
Technology	0602301E	8.2	14.1	17.4	15.8	9.5	11.9
	0602712E	2.0	0.1	0.8	1.6	2.9	3.8
	0603570E	2.0	0	0	0	0	0
	DTO Total	22.5	24.2	29.8	31.6	26.8	31.6
IS31	0602234N	2.1	2.0	2.5	2.9	2.9	2.9
Intelligent Control	0603226E	23.0	20.8	31.5	12.1	19.2	20.1
	DTO Total	25.1	22.8	24.0	15.0	22.1	22.9
IS32	0602702F	1.4	2.5	2.5	2.6	2.5	2.6
Information Presenta-	0602232N	0.4	0.4	0.6	0.8	1.0	1.0
-tion and Interaction	0602234N	0.6	0.5	0.9	1.0	1.1	1.1
	0602301E	15.7	17.6	25.4	22.0	19.2	20.9
	0603226E	52.6	63.2	93.8	67.7	106.5	124.3
	DTO Total	70.7	84.2	123.2	94.1	130.3	149.9
IS33	0602234N	1.8	2.4	2.4	2.4	2.4	2.4
Embedded, High-Per-	0602301E	55.3	70.7	60.3	63.7	69.8	70.1
formance Computing	0603226E	6.0	0	0	0	0	0
	DTO Total	63.1	73.1	62.7	66.1	72.2	72.5

Figure III.16. Information Systems and Technology Roadmap Resources (concluded)

TOTALS MAY NOT AGREE DUE TO ROUNDING

INFORMATION SYSTEMS AND TECHNOLOGY ACRONYMS

2–D	Two Dimensional
2AD	2nd Armored Division
2ID	2nd Infantry Division
3–D	Three Dimensional
4ID	4th Infantry Division
ACD	Adaptive Coordinated Defense
ACOM	Atlantic Command
ACT II	Advanced Concept Technology II
ACTD	Advanced Concept Technical Demonstration
ACUS	Area Common User Systems
ADM	Advanced Development Model
AEGIS	
AI	Artificial Intelligence
AJP	Advanced Joint Planning
ALSP	Aggregate Level Simulation Protocol
AMPS	Advanced Mobile Phone Service
AOC	Air Operations Center
ARL	Army Research Laboratory
ARPA	Advanced Research Projects Agency
ASTO	[ARPA]
ATD	Advanced Technology Demonstration
ATM	Asynchronous Transfer Mode
ATO	Air Tasking Order
ATR	Automatic Target Recognition
AWE	Advanced Warfighting Experiment
B-ISDN	Broadband Integrated Services Digital Network
B3	A Level of Security Assurance
BADD	Battlefield Awareness and Data Dissemination
BC2	Battlespace Command and Control
BCBL	[Army] Battle Command Battlelab
BDA	Battle Damage Assessment
BDS-D	Battlefield Distributed Simulation—Development
BFTT	Battle Force Tactical Trainer
BMDO	Ballistic Missile Defense Organization
bps	bits per second
C-in-C	Commander in Chief
C2	Command and Control
C2I	Command, Control, and Intelligence
C2V	Command and Control Vehicle
C3	Command, Control, and Communications
C3I	Command, Control, Communications, and Intelligence
C4	Command, Control, Communications and Computers
C4I	Command, Control, Communications, Computers, and Intelligence
CASE	Computer-Aided Software Engineering
CBU	Consistent Battlespace Understanding
CCTT	Close Combat Tactical Trainer
CECOM	U.S. Army Communications-Electronics Command
CFC	Combined Forces Command
CFOR	Command Forces
CGS	Common Ground Station
CJTF	Commander, Joint Task Force
CMMS	Conceptual Model of Mission Space
COA	Course of Action
COE	Common Operating Environment
CONUS	Continental United States
CORBA	Common Object Request Broker Architecture
CORBUS	CORBA-Compliant Version of a Heterogeneous DCE
COTS	Commercial Off-The-Shelf
CTAPS	Contingency Tactical Air Planning System

DAMA	Demand Assignment Multiple Access
DARO	
DBC	Digital Battlefield Communications
DBMS	Database Management System
DBS	Direct Broadcast Satellite
DCE	Distributed Computing Environment
DDBMS	Distributed DBMS
DEEM	Dynamic Environmental Effects Model
DEW	Directed Energy Weapons
DIF	Data Interchange Format
DIS	Distributed Interactive Simulation
DISA	Defense Information Systems Agency
DISN	Defense Information Systems Network
DMA	Defense Mapping Agency
DMSO	Defense Modeling and Simulation Office
DNA	Defense Nuclear Agency
DoD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DSCS	Defense Satellite Communications System
DSI	Defense Simulation Internet
DSP	Digital Signal Processor
DSS	Decision Support System
DTAP	Defense Technology Area Plan
DTED	Digital Terrain Elevation Data
DTO	Defense Technology Objective
DVI	Data/Voice Integration
Eagle	Army Combat Development Analysis Tool for Studying Corps and Division-Level Force Effectiveness Issues.
EDCS	Evolutionary Design of Complex Systems
EHF	Extremely High Frequency
EIRP	Effective Isotropic Radiated Power
EIS	Engineering Information System
ELF	Extremely Low Frequency
EMD	Engineering and Manufacturing Development
EMI	Electromagnetic Interference
EPA	Environmental Protection Agency
EPLRS	Enhanced Position Location Reporting System
FASTLANE	An Encryption Device
FDR	Future Digital Radio
FEC	Forward Error Correction
FLOP	Floating Point Operations
FO	Fiber-Optic(S)
FPRA	Forecasting, Planning and Resource Allocation
FY	Fiscal Year
Gbps	Gigabit Per Second
GBS	Global Broadcast Services
GCCS	Global Command and Control System
GFLOP	Giga-Floating Point Operations
GHz	Gigahertz
GloMo	Global Mobile Information System
GOTS	Government Off-the-Shelf
GPS	Global Positioning System
H/W	Hardware
HCI	Human-Computer Interface
HCTR	High-Capacity Trunk Radio
HF	High Frequency
HLA	High-Level Architecture
HPC	High Performance Computing
HPCC	High Performance Computing and Communications
HQ	Havequick
IADS	Integrated Air Defense Simulation
IFM	Integrated Force Management
IFSAR	Interferometric Synthetic Aperture Radar
INC	Internet Controller
IP	Internet Protocol
IPng	Internet Protocol, Next Generation
IR&D	Internal Research and Development

IS&T	Information Systems and Technology
ISDN	Integrated Services Digital Network
ISR	Intelligence, Surveillance, and Reconnaissance
ISxx	IS&T DTO Number Xx
ITU-TSS	International Telecommunications Union Telecommunication Standardization Section (Formerly Comité Consultatif International Des Télégraphique Et Téléphonique [CCITT])
IU	Image Understanding
IUA	Image Understanding Architecture
IW	Information Warfare
JCS	Joint Chiefs of Staff
JMASS	Joint Modeling and Simulation System
JOINT STARS	Joint Surveillance Target Attack Radar System
JPS	Joint Precision Strike
JPSD	JPS Demonstration
JSIMS	Joint Simulation System
JTCTS	Joint Tactical Combat Training System
JTF	Joint Task Force
JTFC2	JTF Command and Control
JWARS	Joint Warfare System
JWID	Joint Warrior Interoperability Demonstration
kbps	Kilobits Per Second
km	Kilometers
LAC	Local Attack Controller
LAN	Local-Area Network
LES	[DISA] Leading Edge Services [Network]
LOS	Line of Sight
LPI/D	Low Probability of Interception/Detection
M&S	Modeling and Simulation
Mbps	Megabits Per Second
MCC	Microelectronics and Computer Technology Consortium
MCE	Modular Control Element
MCOPS	Maritime Campaign Operations Planning System
MICOM	U.S. Army Missile Command
MLS	Multilevel Secure
MMITS	Modular, Multifunction Information Transfer System
ModSAF	Modular Semi-Automated Force
MOUT	Military Operations in Urban Terrain
MPP	Massively Parallel Processors
MRL	Multiple Rocket Launcher
MSRR	Modeling and Simulation Resource Repository
N-ISDN	Narrowband Integrated Services Digital Network
NASA	National Aeronautics and Space Administration
NASM	National Air and Space [Warfare] Model
NCCOSC	Naval Command, Control and Ocean Surveillance Center
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NRaD	NCCOSC Research and Development Division
NRL	Naval Research Laboratory
NSA	National Security Agency
NSF	National Science Foundation
NSS	Naval Simulation System
NSSN	Next Generation Attack Submarine
OCONUS	Outside Continental United States
OOD	Object-Oriented Database
OODBMS	Object-Oriented DBMS
ORB	Object Request Broker
OTM	On the Move
PC	Personal Computer
PCI	Peripheral Component Interface
PCMCIA	Personal Computer Memory Card International Association

PCS	Personal Communications System
POTS	Plain Old Telephone Service
PPP	Predictive Planning and Preemption
R&D	Research and Development
RAP	Radio Access Point
RBV	Rapid Battlefield Visualization
RDEC	[CECOM] Research Development Engineering Center
RF	Radio Frequency
RFI	RF Interference
RFPI	Rapid Force Projection Initiative
RSTA	Reconnaissance, Surveillance, Target Acquisition
RL	U.S. Air Force Rome Laboratory
S&T	Science and Technology
S/W	Software
SARDB	Survivable Armed Reconnaissance on the Digital Battlefield
SAS	Survivable Adaptive Systems
SATCOM	Satellite Communications
SBD	Simulation Based Design
SC-21	21st-Century Surface Combatant
SHF	Super High Frequency
SINCGARS	Single-Channel Ground and Airborne Radio System
SONET	Synchronois Optical Network
SPC	Software Productivity Consortium
SSCN	Secure Survivable Communications Network
STOW	Synthetic Theater Of War
STRICOM	[U.S. Army] Simulation, Training, and Instrumentation Command
T&E-EW	Test and Evaluation - Electronic Warfare
TCP	Transmission Control Protocol
TD ATD	Total Distribution ATD
TEED	Tactical End-to-End Encryption Device
TF	Task Force
TFLOP	Tera-Floating Point Operations
TFXXI	Task Force Twenty-One
THAAD	Theater High-Altitude Air Defense
TMD	Theater Missile Defense
TMG	Tactical Multinet Gateway
TOC	Tactical Operations Center
TRADOC	[U.S. Army] Training and Doctrine Command
TRANSCOM	Transportation Command
TRI-TAC	Tri-Service Tactical Communications
UAV	Unmanned Aerial Vehicle
UDP	User Datagram Protocol
UHF	Ultra-High Frequency
USFK	United States Forces Korea
VHF	Very High Frequency
VR	Virtual Reality
WAN	Wide-Area Network
WARSIM 2000	Warrior Simulation for year 2000
XVIII ABC	18th Airborne Corps

IV. FY 1997 DEFENSE TECHNOLOGY AREA PLAN FOR GROUND VEHICLES AND WATERCRAFT

1. INTRODUCTION

1.1 Definition/Scope

The Ground Vehicles and Watercraft Technology Area addresses the platform and systems technologies that support Ground Vehicles (i.e., land combat and tactical vehicles & amphibious vehicles with a ground combat role), Surface Ship Combatants, Submarines, and Unmanned Undersea Vehicles (UUVs). For Ground Vehicles, this includes intra-vehicle digitization, propulsion and power, track and suspension, chassis and turret structures, vehicle subsystems, hydrodynamics, integrated survivability, fuels and lubricants, and integration technologies. For Surface Ship Combatants and Submarines this includes structural systems, maneuvering and seakeeping, power and automation, and signature control. For UUVs, this includes electro-chemical and thermal technologies for energy/propulsion systems; guidance, and effectors and mission control technologies; and vehicle communications, navigation and stealth/silencing technologies.

The Subareas covered in this DTAP are identical to those found in the 1995 Surface/ Undersurface Vehicles DTAP and are identified in Figure IV.1. See Resource Appendix for funding of this Defense Technology Area.

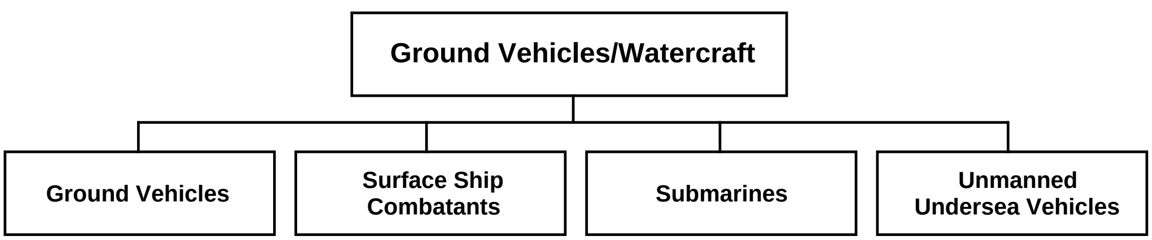


Figure IV.1. Area Taxonomy

1.2 Strategic Goals

The strategic goals for this Technology Area are driven by the warfighting needs described in Section 1.3 and the realization that budget constraints will exist for the foreseeable future thus impacting the acquisition and operation of all future military systems. Therefore, the primary strategic goal is to develop and demonstrate technologies to enable technological superiority of ground vehicle/watercraft systems over those of current and future adversaries, while significantly reducing the life cycle cost. Budget constraints will also restrict the number of deployed systems thus putting a premium on the ability of new systems to remain on station longer, whatever the threat.

Therefore, another strategic goal is to provide options which will enable major improvements in survivability and reliability. With fewer new systems, it's also a goal to develop and demonstrate technology aimed at system upgrades. Achieving these goals in the first decade of the twenty-first century will contribute significantly to the military effectiveness of future vehicle systems addressed under this Technology Area Plan.

1.3 Acquisition/Warfighting Needs

The Ground Vehicles and Watercraft Technology Area supports the Land and Littoral Joint Warfighting Capability Areas (JWCA) and the Strategic Mobility and Sustainment JWCA. The Land and Littoral JWCA domain extends from 300 nautical miles at sea, through all forcible entry operations (amphibious, airborne, air assault, special operations), sustained land combat, and operations other than war. The Strategic Mobility and Sustainment JWCA is concerned with the timely arrival of all forces, equipment and sustainment to provide force closure, and to support campaign objectives during Major Regional Contingencies (MRC), or the ability to execute an Operation Other Than War (OOTW). Key planned products and transition opportunities are shown in Figure IV.2.

Land combat vehicles, integrated with the combined arms force, are the central component of the land battle and 'Force XXI'. Amphibious assault vehicles are likewise key to littoral operations and a seamless transition from sea to ground maneuver. The Navy's current doctrine, "Forward ...From the Sea", emphasizes the littoral region as the primary operational area of surface ship combatants, submarines, and unmanned undersea vehicles (UUVs) as well as continuing the more traditional role of protecting the sea lanes. In support of this doctrine, surface ship combatants, submarines and UUVs play a critical role in the Navy's joint mission support areas of Strike, Littoral Warfare, Strategic Deterrence, Surveillance, Strategic Sealift, Forward Presence, and Readiness.

Subarea	Planned Products	Timeframe 2000	2005	2010
Ground Vehicles	Imp Armor, Signature Supression, Active Protect, Hit Avoidance	Abrams, Bradley, Tactical Vehicles	Scout (SV), Recon Scout Vehicle, Crusader	Future Tank (FMBT)
	Band Track, Semi-Active Susp, Advanced Prop, Elec Drive	Abrams, Bradley, Tactical Vehicles	SV	FMBT, FIV
	Lightweight Materials, Composite Structures		SV, Recon Scout Vehicle	FMBT, Future AAV, FIV
	Elec Architecture, Adv Crew Station Tech	Abrams, Bradley Tactical Vehicles	SV	FMBT, FIV

Figure IV.2. Anticipated Technology Transition Opportunities

Subarea	Planned Products	Timeframe 2000	2005	2010
Surface Ship Combatants	Integrated Topside Systems	LPD17	SC21	CVX
	Combat Tolerant ADH Systems		SC21	CVX, Far-term Fast Sealift
	Automated HM&E Control Systems		SC21	CVX
	Advanced Degaussing System	MCM1, MHC51, LPD17	SC21	CVX
	Uninterruptible Electric Power		SC21	CVX
Submarines	Machinery Truss Support System		NSSN Upgrades	Post -NSSN
	Integrated Stern			Post-NSSN
	Quiet Electric Drive		NSSN Upgrades	Post-NSSN
	EM Signature Control	NSSN, SSN 21		Post-NSSN
	Low Cost Propulsor		NSSN, Trident, SSN 688	Post-NSSN
	Advanced Vibration Reducer	NSSN, SSN 21 Upgrades		Post-NSSN
Unmanned Undersea Vehicles	Battery	SDV, MK30		Common Battery
	Thermal Energy	LMRS		Reconfig. UUV
	Torpedo Energy		MK48, LHT, ATT	Smart Torpedo
	Precision Navigation	LMRS		Reconfig. UUV
	Controllers	LMRS, MK30		Reconfig. UUV
	Communications	LMRS, ATD		Reconfig. UUV
	Silencing	LMRS		Reconfig. UUV

Figure IV.2. Anticipated Technology Transition Opportunities

2. DEFENSE TECHNOLOGY OBJECTIVES (DTO)

The following provides a listing of DTOs by each of the subareas. A description of the DTOs is provided in the DTO Annex.

2.1 Ground Vehicles

GV.01.06.A Advanced Ground Vehicle Systems
GV.02.08.ANE Ground Vehicle Integrated Survivability
GV.03.00.ANE Advanced Ground Vehicle Mobility Systems
GV.04.01.A Ground Vehicle Electronic Systems
GV.05.00.AN Ground Vehicle Chassis and Turret Technologies

2.2 Surface Ship Combatants

GV.06.02.N Power and Auxiliary Systems
GV.07.02.N Hull Systems
GV.08.02.N Integrated Topside Systems
GV.09.01.NE Automation

2.3 Submarines

GV.10.00.NE	Advanced Machinery Truss Support System
GV.11.02.N	Maneuvering Systems
GV.12.01.N	Signature Control Systems
GV.13.02.N	Structural Systems

2.4 Unmanned Undersea Vehicles

GV.14.07.N	UUV Technology

3. TECHNOLOGY DESCRIPTION

3.1 Ground Vehicles Subarea

3.1.1 Warfighter Needs

The Ground Vehicle technology plan addresses warfighter Operational Capability Requirements (OCRs) per TRADOC Pamphlet 525-66, 1 Dec 95. In the short term (1-2 years), the ground vehicle technology program concentrates on transition of affordable, easily integrateable technologies which address mobility, survivability and deployability for upgrade of existing, fielded systems. In the mid-term (3-5 years), the ground vehicle community will conduct subsystem and integrated vehicle system level Advanced Technology Demonstrations (ATDs) to provide pre-milestone zero technology answers needed for the start of critical system programs. Virtual Prototyping will develop and demonstrate tools that can enable savings in new starts; cost, schedule, and risk may be reduced 30% through a more thorough concept alternative exploration at program initiation. Technical and affordability goals will be demonstrated through efforts in the Advanced Ground Vehicle Systems DTO. Far term (6+ years) plans include further advancements in technology areas such as doubling cross country ride performance and platform stability for the combat vehicle fleet with ARPA/TARDEC active/semi-active suspension technology, as well as tactical operations employing highly agile, robust semi-autonomous ground vehicles. These technologies will provide new critical warfighting capabilities for the Future Main Battle Tank, Scout Vehicle, future infantry vehicle concepts, and system upgrades across combat and tactical fleets.

3.1.2 Ground Vehicles Overview

3.1.2.1 Goals and Timeframes. Goals are based on retaining current levels of durability and life with decreases in maintenance and supply burden.

GOAL AREA	2000	2005
Reduce Tank Weight (%)	20	40
C130/141: Transportable Medium Class Vehicles	Yes	—
Internal Helo Transportable Light Class Vehicles	Yes	—
Increase Force Effectiveness Through Integrated Survivabiltiy (%)	40	50
Reduce Vehicle Radar and Thermal Signatures (%)	50	70
Demonstrate Active Protection	100m Smart CE	KE
Demonstrate Computer Aided Driving	On-road	Off-road
Demonstrate Semi-Autonomous Operations	Tactical	Combat
Reduce Tank Propulsion Volume (%)	—	25
Demonstrate Electric Drive by Weight Class (Tons)	8-12	40-50
Improve Crew Station	2X Efficiency	Voice Activated
Improve Electronic Architecture	10X Efficiency	Neural Net

Figure IV.3. Ground Vehicles S&T Goals

3.1.2.2 Major Technical Challenges. This technically broad area has numerous challenges to achieving deployability goals while increasing survivability and lethality against future threats. Crew station technologies similar to aircraft which allow crew size reduction at a reduced crew workload must be accomplished. Driver automation techniques which improve mobility and increase utility of the vehicle driver must be integrated. Vehicle data rates and software lines of code approach those of fighter aircraft, but must be designed and maintained at 10% of the cost. The Advanced Ground Vehicle Systems DTO is addressing these challenges. Similarly the Ground Vehicle Integrated Survivability DTO is confronting unique technical barriers. Signature reduction technologies similar to aircraft must be robust in a dirty environment with high shock loading. Visual signature reduction concerns unique to the ground vehicle must be addressed. Mobility component weight and volume must be reduced while power increases to support subsystem electrical loads. Critical to achieving these technical challenges in an affordable and timely manner is the use of Virtual Prototyping (VP) and Integrated Product and Process Development (IPPD). VP and IPPD have been incorporated into Ground Vehicle ATDs requiring quality, affordability and producibility to be among the primary development goals in addition to the traditional technical performance.

3.1.2.3 Related Federal and Private Sector Efforts. Ground vehicle related Independent Research and Development programs amounting to $50M+ per year are leveraged. Basic electric drive technologies are transitioned through the National Automotive Center's initiatives with the Department of Energy and USCAR. All vehicles, except the tank, use uprated commercial heavy duty engines. Electronic bussing of vehicle power and data are based on commercial practice and forced to conform to commercial codes, albeit at much increased data rates. The military virtual prototyping vision is based on Boeing Aircraft and Chrysler Corporation current practice.

3.1.3. S&T Investment Strategy

3.1.3.1 Technology Demonstrations. Advanced Technology Demonstration (ATDs) and Technology Demonstrations (TDs) are planned in all technical areas.

a. Crewman's Associate ATD will demonstrate advanced crew station soldier machine interfaces for ground combat vehicles achieving a reduction in crew members and/or crew workload with improved situational awareness, operation on the move and night operations.

b. Hit Avoidance ATD will demonstrate electronic warfare and active protection in an affordable combination with 20-80% gains in system survivability through an integrated hit avoidance suite which is battlefield reconfigurable to meet evolving threats and modular for tailoring to other vehicles and battlefield needs/locations.

c. Composite Armored Vehicle ATD will demonstrate a 33%+ structural weight reduction in a modern lightweight vehicle design through the full integration of structure, armor and signature management while validating producibility, repairability and affordability in parallel with its performance oriented goals.

d. Ground Propulsion and Mobility TD will demonstrate advanced mobility technologies in track, suspension, propulsion and electric drive technologies which will increase ride performance and platform stability of ground vehicle systems.

e. Advanced Tank Technologies TD will demonstrate the vehicle level physical and electronic integration of the Hit Avoidance, Combined Arms Command and Control, Target Acquisition and Crewman's Associate ATDs into a leap ahead future tank system.

f. Scout Vehicle TD will demonstrate all relevant chassis, sensor, survivability, communications and mobility technologies, which address scout-specific signature management, battlefield transportability and platform stability issues, in an electronically integrated system. This TD will use the results of the ARPA study of an all-electric vehicle applied to a scout mission.

g. Tactical Robotic Ground Vehicle TD will demonstrate semi-autonomous navigation in urban and tactical terrain.

h. Reconnaissance Scout Vehicle will demonstrate vehicle integration and mission payloads to fulfill USMC and SOCOM missions that require internal transport via V-22 tilt rotor aircraft. Propulsion and suspension are key to developing the lightweight, narrow class of vehicles. This program will address ARPA study results of an all-electric vehicle.

i. Integrated Electric Propulsion, an ARPA sponsored program, will demonstrate hybrid electric drive power systems, to include integration of components into an advanced electric drive architecture. Technology will be applied to Army and Marine Corps scout vehicle demonstrations and will be scaleable to FMBT needs.

3.1.3.2 Technology Development. There are five ground vehicle technology development efforts:

- System Integration optimizes future system performance through establishing technology requirements/needs and identifying future concept potential resulting from the new set of technological capabilities.
- Chassis and Turrets investigates new material technologies applied to both ground vehicle chassis and turret requirements of new and system upgrades. New lightweight structures and armor, signature treatments together with affordability constraints are the primary challenges.
- Integrated Survivability provides the ground vehicle an integrated set of survivability capabilities by achieving a balance of detection, hit, penetration and damage avoidance technologies.
- Mobility focuses on tracked wheeled and amphibious ground vehicles. It includes track and suspension, engine, transmission, propulsion unit (amphibious), fuels and lubricants and various ancillary components, e.g., cooling and air filtration systems.
- Intra-Vehicle Digitization develops and integrates the vehicle digitization technologies which will enable current and future ground vehicles to effectively function on the digital battlefield.

3.1.3.3 Basic Research. The most notable basic research efforts are: the University Research Initiative (URI) program for diesel engines at the University of Wisconsin, the National Automotive Center consortium for automotive research at the University of Michigan, technology efforts in dynamic modeling at the University of Iowa, computational advancements for vehicle dynamics at the ARO Center for Advanced Computing and Mathematics and the Army Research Laboratory's programs in advanced materials, composite structures and gas turbine engine technology.

3.2 Surface Ship Combatants Subarea

3.2.1 Warfighter Needs

Figure IV.4. portrays improvements in warfighter needs addressed by this subarea. Correlation between the needs and goals defined in Section 3.2.2.1 are also shown in this figure. The payoff quantification is based on a balanced combination of the payoff areas for the DDG-51 Flight IIA.

Goal Area Numbers												Payoffs	
1	2	3	4	5	6	7	8	9	10	11	Warfighter Needs	2000	2005
✓	✓	✓	✓		✓						Decrease In Probability Of Mission	50%	85%
				✓						✓	Decrease In HM&E Acquisition Cost	15%	30%
				✓				✓	✓		Decrease In HM&E Operation &	35%	55%
✓	✓					✓	✓	✓			Increase In Offensive Payload	50%	100%
					✓	✓		✓			Increase In Mobility	20%	30%
				✓		✓		✓			Increase In Sustainability	20%	35%
✓	✓				✓						Increase In Littoral Operating Envelope	20%	25%

Figure IV.4. Surface Ship Combatants S&T Impact on Warfighter Needs

3.2.2 Surface Ship Combatants Overview

3.2.2.1 Goals And Timeframes. The goals listed in Figure IV.5. represent potential improvements in HM&E subsystems for the indicated timeframes. Indicated improvements are relative to the notional Flight IIA upgrade to the DDG-51 Class Destroyers.

#	GOAL AREA	2000	2005
1	Reduction in Signatures	90%	97%
2	Reduction in EM Interference and Emissions	99%	-
3	Reduction in Vulnerability	40%	50%
4	Improvement in Damage Control	25%	50%
5	Reduction in Manning	20%	40%
6	Improvement in Seakeeping	20%	35%
7	Reduction in Light Ship Weight Fraction	20%	25%
8	Increase in Power Density	30%	40%
9	Reduction in Fuel Consumption	20%	30%
10	Reduction in Maintenance Cost	25%	40%
11	Reduction in Manufacturing Cost	10%	20%

Figure IV.5. Surface Ship Combatant S&T Goals

3.2.2.2 Major Technical Challenges. The Surface Ship Combatant S&T community is facing numerous technical challenges critical to the development of affordable ships that will meet future requirements such as operation in littoral regions. Principal challenges include: a) reduce both topside weight and volume while reducing signatures and increasing sensor performance; b) minimize weight and volume of HM&E systems while increasing combat tolerance and decreasing life cycle costs; c) improve damage fight through and recovery while minimizing manning levels and equipment redundancy.

3.2.2.3 Related Federal And Private Sector Efforts. The Surface Ship Combatant subarea leverages both private sector and other government investments. For instance, ship hardening efforts relate to the FAA Commercial Aircraft Hardening program, the Foreign Ship and Submarine Vulnerability Program, and weapon

development programs. Another example is that the Power and Automation area has an effort in power electronic building blocks (PEBBs) which is coordinating with the Department of Energy, the Advanced Research Project Agency, the Department of the Army and the Air Force.

3.2.3 S&T Investment Strategy

3.2.3.1 Technology Demonstrations

a. Advanced Enclosed Mast/Sensor System - Demonstrate the capability to fully integrate sensors, electromagnetics, signature reduction, and structures into an affordable mast having improved warfighting capabilities.

b. Advanced Degaussing - Significantly reduce surface ship underwater electromagnetic signatures in order to decrease vulnerability to underwater mines.

c. Littoral Warfare Real Time EMI Frequency Management - Demonstrate the capability to dynamically manage combat system frequencies and modes of operation while significantly reducing EMI.

3.2.3.2 Technology Development

a. Structural Systems - Develop a probabilistic based approach for ship structural design; apply high quality organic composite systems to ship structures in an affordable manner; and develop affordable concepts for minimization of damage to ships caused by a wide array of weapons.

b. Power and Automation - Develop an uninterruptible shipboard electric power system and an affordable electric propulsion option; develop alternative power generation concepts such as diesel-fed fuel cells for auxiliary power; and develop automated damage control systems and associated tactical decision aids.

c. Signature Control - Develop ship topside and hull concepts to meet future signature goals (RCS, IR and EMI); develop acoustic silencing techniques for sea connected piping systems and hull appendages; and develop improved magnetic sensors and control techniques for secondary magnetic fields.

d. Maneuvering and Seakeeping - Improve ship seakeeping by reducing ship motions in high seas through hull shaping and motion control devices; reduce hull resistance and wake signatures; and improve propulsor quieting and efficiency.

3.2.3.3 Basic Research. The principal basic research efforts which directly support exploratory and advanced development efforts include: micromechanics analysis for high-power solid-state devices, artificial intelligence for fault-tolerant electric circuit breakers, and unsteady Reynolds averaged Navier-Stokes for hydrodynamics.

3.3 Submarines Subarea

3.3.1 Warfighter Needs

The Submarine Subarea develops technologies to insure U.S. submarine stealth superiority and to provide maximum performance at minimum cost. These efforts provide essential technologies for submarines to support joint warfighting capabilities for: decisive combat against regional forces; a range of capabilities for lower-end operations; countering weapons of mass destruction; and near-perfect real-time knowledge and communication. Figure IV.6. portrays improvements in warfighter needs addressed by this subarea. The baseline is the SSN 688.

	Payoffs	
Warfighter Needs	**2000**	**2005**
Decreased Probability Of Mission Loss	10%	20%
Reduction in HM&E Acquisition Cost	5%	20%
Reduction in HM&E O&S Cost	5%	15%
Increase In Payload	10%	25%
Increase In Sustainability	5%	15%
Expansion of Submerged Operating Envelope	10%	25%
Reduction in Time to IOC	10%	30%

Figure IV.6. Submarine S&T Impact on Warfighter Needs

3.3.2 Submarines Overview

3.3.2.1 Goals and Timeframes. All goals are referenced with respect to the SSN 688 Class with the exception of signature reduction goals which are referenced with respect to SSN21.

GOAL AREA	2000	2005
Reduction in Design Cycle Cost & Time	10%	20%
Reduction in Construction Cost & Time	10%	20%
Reduction in Maintenance Cost & Time	10%	20%
Reduction in Vulnerability to Weapons Effects	30%	80%
Reduction in Signatures - Non-Littoral	40%	80%
Reduction in Signatures - Littoral	40%	80%
Improvement in Submerged Operating Envelope	10%	20%
Reduction in HM&E Weight & Volume Fraction	-	10%
Increase in Thrust per Propulsion System Weight & Volume	5%	30%
Reduction in HM&E Manning Demand	-	40%
Reduction in Damage Recovery Time	20%	50%

Figure IV.7. Submarine S&T Goals

3.3.2.2 Major Technical Challenges. The driving design requirements for submarines are control of acoustic signatures and shock resistance. These requirements influence all submarine systems and hence submarine costs. To achieve further reductions in acoustic signature and to reduce the cost of quieting and shock resistance, new approaches which take a systems-level view, must be developed. Key challenges are: the identification and reduction of force transmissions that result in radiated noise; an improved understanding of the hydrodynamic forcing mechanisms and the resulting response and acoustic radiation of structural components to these forces; an understanding of complex energy dissipating mechanisms for acoustic/shock isolation systems; and the capability to predict highly complex hydrodynamic flows to reduce the scope of experimental evaluation and enable development of propulsors and maneuvering concepts. Non-acoustic signature technology is growing in importance due to emphasis in littoral operations.

3.3.2.3 Related Federal and Private Sector Efforts. The related federal and private sector efforts are limited due to the unique operating environment and the security issues associated with nuclear submarines. Research developments are monitored for potential relevance and coordination with identified related efforts is achieved through direct interaction and informal communication with the scientific community. Cooperation with foreign governments is limited by national security issues, although the United Kingdom has provided platforms for joint electromagnetic signature reduction efforts.

3.3.3 S&T Investment Strategy

3.3.3.1 Technology Demonstrations

a. Advanced Vibration Reducer—The goal of this demonstration is to develop a full-scale prototype system which reduces submarine far-field acoustic signature.

3.3.3.2 Technology Development

a. Signature Control—Objectives are to develop technologies to control acoustic and non-acoustic submarine signatures to insure the stealth superiority of U.S. submarines against all threats and at economical cost. Acoustic signatures remain the most exploitable signature. Major sources of acoustic signatures are noise from internal sources, transient noise from payload launch and other discharges, flow noise over the hull and appendages, propulsor generated noise, and active sonar interrogation. Submarines are vulnerable to non-acoustic detection when operating in the littorals or on/near the surface.

b. Structural Systems—Objectives are to develop technologies to: build structures that provide balanced static and shock performance; provide shock and acoustic attenuating structures to support utilization of COTS equipment for cost reduction; support modular construction for cost reduction; and

develop computational Live Fire capability to reduce the amount of explosive shock testing.

c. Power & Automation—Objectives include reduction of weight, volume, energy, and maintenance impact of non-nuclear propulsion, machinery, and electrical systems. These systems support all aspects of operations - propulsion, electric power, combat systems, payload launch, sonar, and life support while meeting acoustic, shock, and SUBSAFE requirements.

d. Maneuvering & Seakeeping—The objective is to develop: lower cost and improved performance propulsor concepts with improved maneuverability for littoral operations; fail-safe maneuvering systems; and simulation-based design capability to support new concept development and reductions in design cost. This area is closely coupled with propulsor acoustics.

3.3.3.3 Basic Research. The basic research needs are improved physics-based understanding of structural acoustics, hydroacoustics, static and dynamic structural response, hydrodynamics, and electric system stability. In addition, materials that provide improved acoustic and non-acoustic performance and are compatible with deep submergence requirements are needed.

3.4 Unmanned Undersea Vehicles (UUV) Subarea

3.4.1 Warfighter Needs

The high priority missions of UUVs have been identified in the UUV Program Plan, April 1994, as: mine reconnaissance, surveillance, intelligence collection and tactical oceanography. All UUV missions and ASW targets require: reduced life cycle cost, practical, long range/endurance propulsion systems with 4-7X the energy density of the zinc/silver oxide battery; a 10X improvement in low speed (hover<4 knots) control in energetic shallow water environments for sensors and vehicle recovery; a 10X improvement in mission reliability/robustness; a 30X increase in communications data rate for offboard sensor data processing and mission monitoring; a 10X improvement in affordable, covert precision navigation for marking targets, navigating tributaries and for vehicle recovery; and for clandestine operations and sensors, the low frequency acoustic signature must be reduced by 6 dB in order to meet SEAWOLF stealth requirements and the Electro-Magnetic signature must be reduced 10X in order to meet sensor and target requirements. PMO-403 is the transition agent for all UUV technologies. The technology under development is available for the potential integration into the LMRS and the MK30 ASW Training Target. For weapons, reduced life cycle cost, environmentally benign, high power/energy density propulsion systems with 2-4X the power density of the MK48 ADCAP are required. PMO-402 and PMO-406 are the transition agents for weapon technologies. The technologies under development are available for potential integration into the multi-purpose and half-length torpedoes and torpedo defense initiatives.

3.4.2 Unmanned Undersea Vehicles Overview

ARPA established a UUV Technology and Rapid Prototyping Program in the late 1980's. ONR's complementary Science and Technology Program was established in FY95 following the publication/release of the Navy's UUV Program Plan, April 1994.

3.4.2.1 Goals and Timeframes. The goals delineated below meet the needs of the fleet and realize the warfighting potential of UUVs, ASW Training Targets and Weapons. The improvements indicated below for UUVs are based upon and relative to zinc/silver oxide undersea batteries for energy, the Adjustable Diversity Acoustic Telemetry System (ADATS) for undersea communications, and the tactically sized Large Diameter UUV (LDUUV). The improvements for torpedo energy systems is relative to the MK48 ADCAP Torpedo.

GOAL AREA	2000	2005
Increase in low rate (UUV) energy density	4X	7X
Increase in high rate (torpedo) energy density	2X	4X
Reduction in energy systems life cycle cost	50%	75%
Improvement in trajectory/hover control/accuracy	2X	10X
Reduction in autopilot design, maintenance cost and time	50%	75%
Improvement in mission reliability/robustness	4X	10X
Improvement in navigational accuracy	10X	100X
Reduction in navigation system cost	50%	-
Increase in acoustic communications data rate	20X	30X
Reduction in acoustic signatures	50%	75%
Reduction in magnetic signatures	4X	10X

Figure IV.8. Unmanned Undersea Vehicles S&T Goals

3.4.2.2 Major Technical Challenges. The major technical challenges are: energy density and cycle life for batteries; affordable robust thermal combustors and high efficiency compact heat engines for environmentally benign propulsion; precise trajectory control at low speeds in energetic complex (nonlinear) shallow water environments and fault tolerance for reliability and advanced mission capability; high data rate coherent shallow water (multipath) undersea acoustic communications for offboard data processing and mission monitoring; affordable, covert, tactically sized, terrain matching/mapping precision navigation system; acoustic and electro-magnetic signature reduction by advanced sensors, designs, coatings and passive and active cancellation techniques.

3.4.2.3 Related Federal and Private Sector Efforts. ARPA and the DOE are developing new power sources that could have undersea vehicle applications. Promising technologies are undergoing laboratory testing at Navy laboratories. NSF is funding NPS to investigate intelligent control systems for autonomous underwater robotics applications.

3.4.3 S&T Investment Strategy

3.4.3.1 Technology Demonstrations. Laboratory and at-sea testing/ demonstration is an important part of the technology development process in order to

benchmark the performance and progress, and to ensure useful end products. In FY97, the following at sea technology demonstrations are planned: obstacle avoidance, full duplex undersea acoustic communications, and in-stride GPS. In FY98, the following energy system demonstrations are planned: 100 Ah lithium cobalt oxide rechargeable battery and long range thermal wick/Rankine. In the mid and far-term, at-sea technology demonstrations will focus upon: nonlinear adaptive autopilot controller, high rate acoustic communications, geophysical navigation, mission robustness, wick/Stirling, and JP5-O_2 (chemical) weapon propulsion system.

3.4.3.2. Technology Development. Technology advances in all of the constituent areas of undersea vehicles are required in order to meet the Fleet requirements and to realize the full potential of UUVs and Weapons. Technology development focuses upon: high energy/power electric and thermal propulsion systems using lithium/lithium alloy, and JP5- O_2 based technologies; precision guidance and control technology using adaptive nonlinear autopilot effector control and artificially intelligent mission control in environmentally complex nonlinear environments; coherent signal processing for high rate undersea acoustic communications in the shallow water environment, terrain matching/mapping covert precision navigation; and acoustic and EM signature reduction by passive and active methods.

3.4.3.3 Basic Research. New catalysts and manufacturing processes are under development for rechargeable batteries and fuel cells. New high temperature combustors, chemical reactants, and high efficiency turbines and engines are under development for thermal systems. Artificial intelligence, neural networks and fuzzy logic are being added to vehicle controllers to improve performance and reliability through a learning process.

4. TECHNOLOGY AREA ROADMAPS AND RESOURCES

A time-phased layout of major Technology Development and Technology Demonstration efforts and their relationship to the DTOs is provided in Figures IV.9.-IV.12. For the purpose of clarity the roadmap is broken out by the four subareas.

4.1 Technology Area Roadmaps—See Figure IV.9.-IV.12.

4.1.1 GROUND VEHICLES ROADMAP

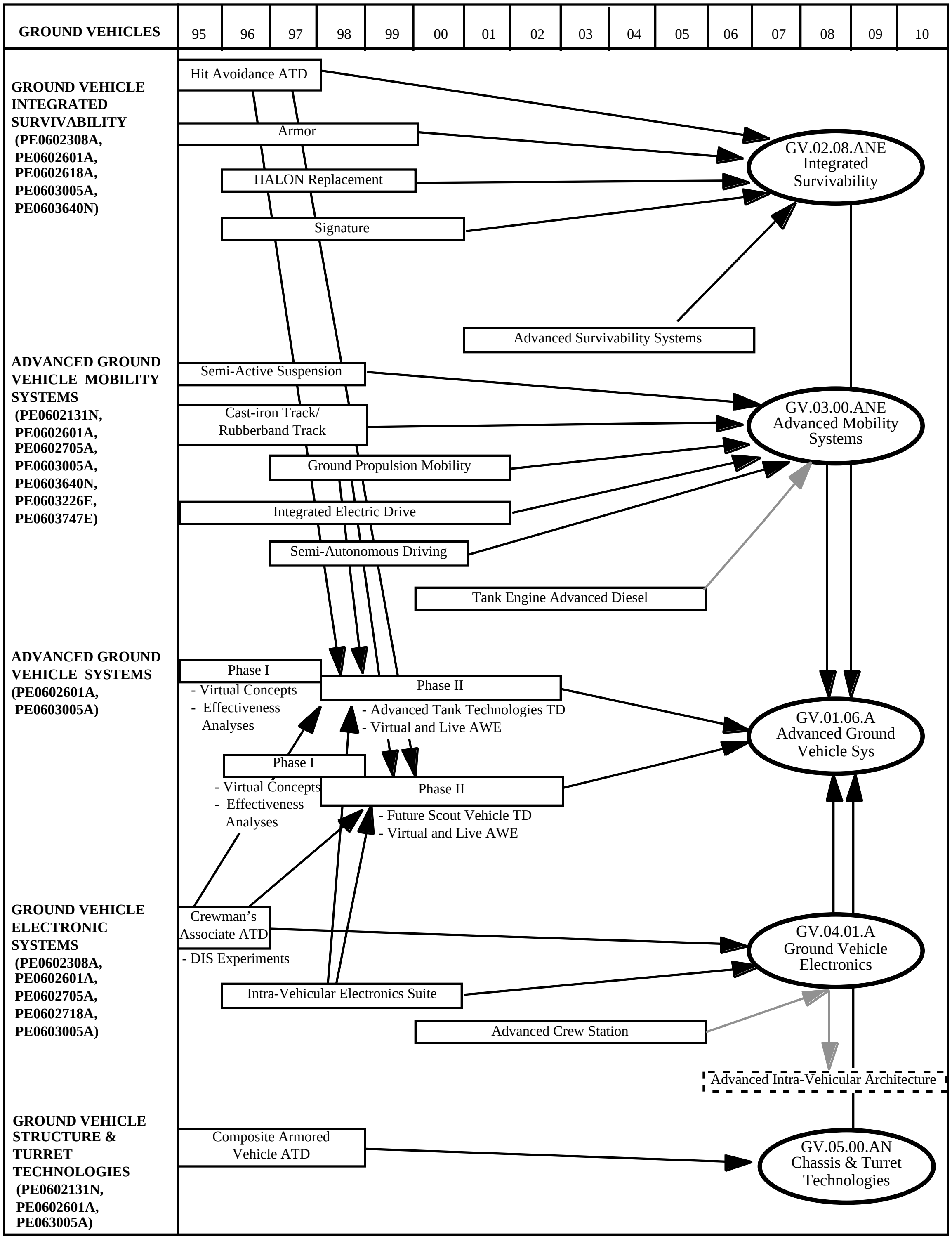


Figure IV.9. Ground Vehicles Roadmap

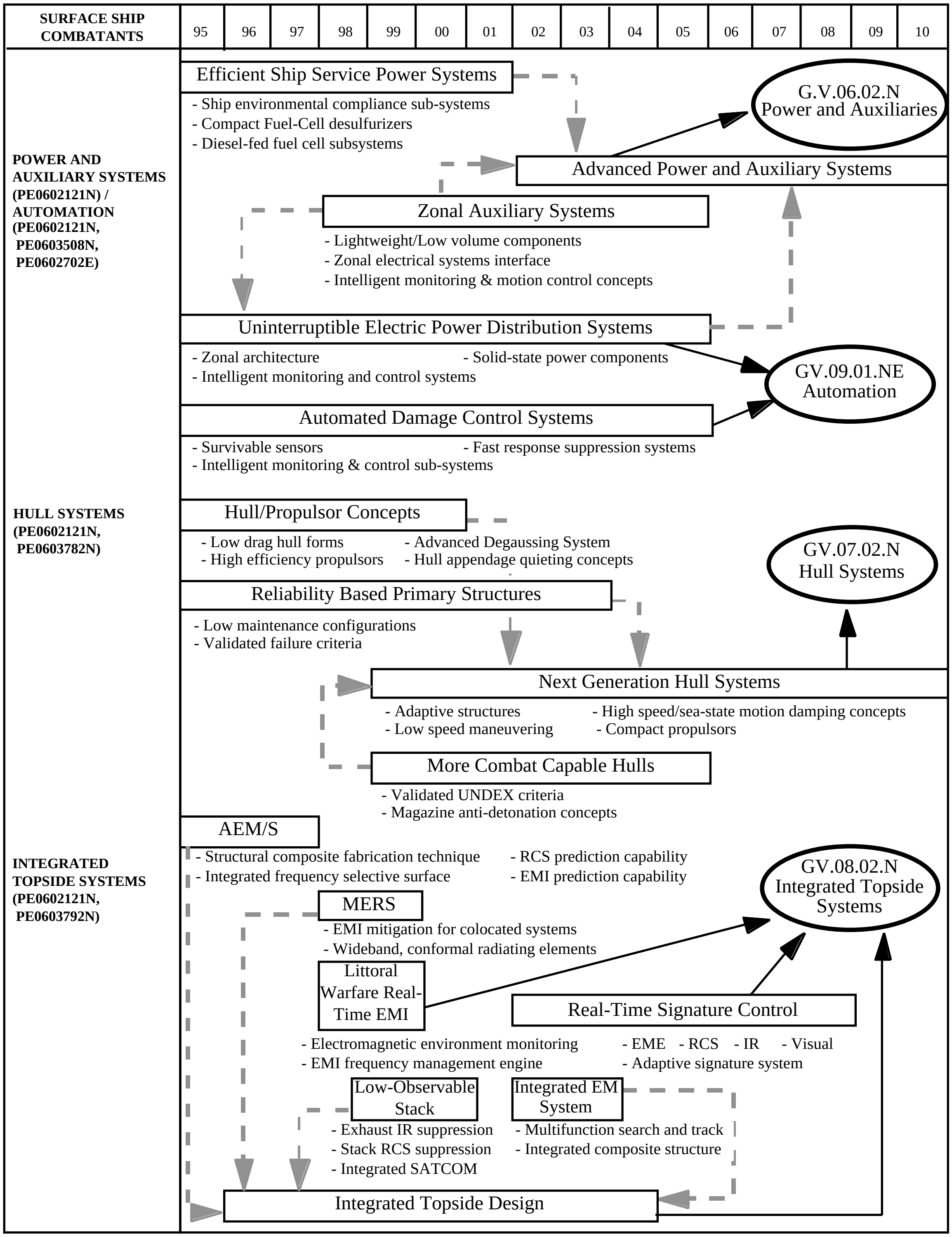


Figure IV.10. Surface Ship Combatants Roadmap

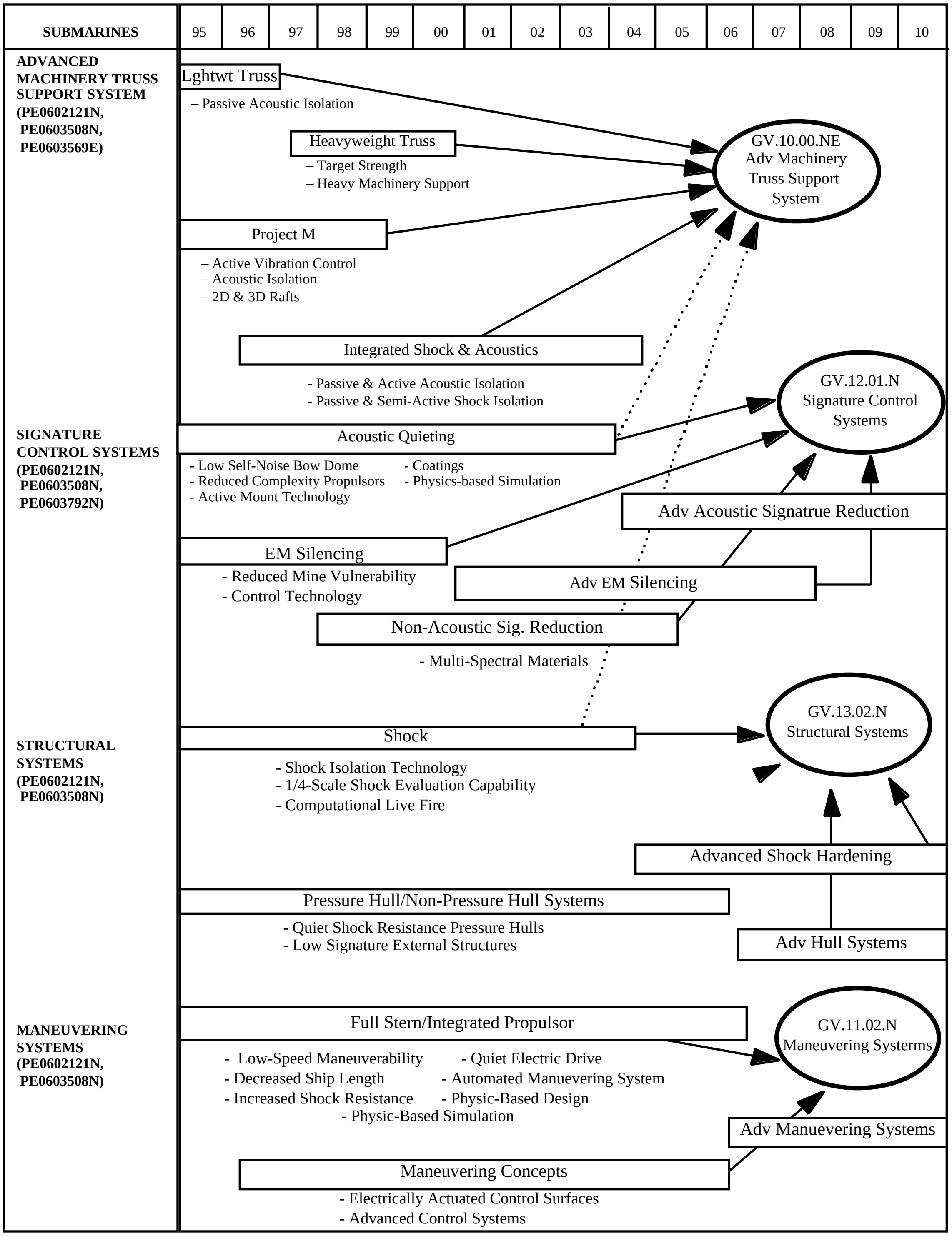


Figure IV.11. Submarine Roadmap

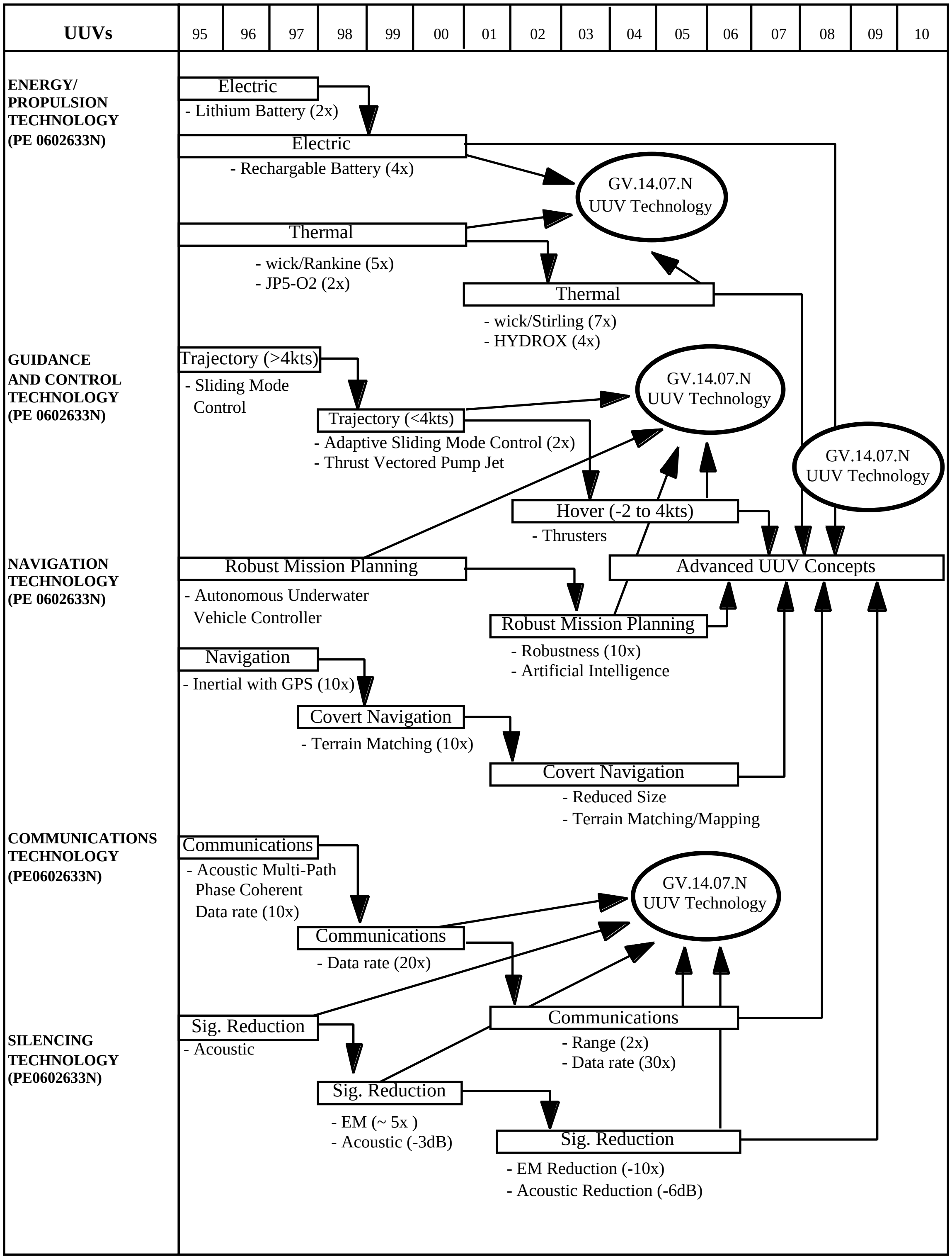


Figure IV.12. Unmanned Undersea Vehicles Roadmap

4.2 Ground Vehicles and Watercraft Technology Area Roadmap Resources ($M)

DTOs	Program Element	$ in millions					
		FY1996	FY1997	FY1998	FY1999	FY2000	FY2001
GV.01.06.A	0602601A	2.5	2.4	2.8	2.9	0.0	0.0
Adva Ground	0603005A	--	--	1.3	20.9	34.7	37.9
Vehicle Systems	DTO Total	2.5	2.4	1.3	20.9	34.7	37.9
GV.02.08.ANE	0602601A	0.9	0.9	1.0	0.9	1.0	0.0
Integrated	0602601A	1.8	4.0	4.2	4.6	0.0	0.0
Survivability	0603005A	7.9	4.8	0.7	0.7	1.6	1.0
	0603640N	--	1.3	1.1	2.0	0.8	2.0
	DTO Total	10.6	11.0	7.0	8.2	3.4	3.0
GV.03.00.ANE	0602131N	2.7	2.8	3.4	3.8	3.7	3.5
Advanced	0602601A	0.6	3.0	2.5	2.4	0.0	0.0
Mobility	0603005A	2.6	4.2	3.8	4.8	4.8	5.7
Systems	0603640N	0.2	2.5	3.9	5.0	8.0	9.0
	0603226E	15.0	20.0	20.0	10.0	0.0	0.0
	0603747E	10.0	0.0	0.0	0.0	0.0	0.0
	DTO Total	31.1	32.5	33.6	26.0	16.5	18.2
GV.04.00.A	0602308A	0.9	0.0	0.0	0.0	0.0	0.0
Electronic	0602601A	1.3	1.5	1.3	0.0	0.0	0.0
Systems	0602705A	0.7	0.7	0.0	0.0	0.0	0.0
	0602716A	1.1	0.8	0.8	0.0	0.0	0.0
	0603005A	1.0	5.8	6.2	7.4	8.6	9.5
	DTO Total	5.0	8.8	8.3	7.4	8.6	9.5
GV.05.00.AN	0602131N	0.3	0.1	0.0	0.0	0.0	0.0
Chassis & Turret	0602131N	1.4	1.3	1.1	0.8	0.7	0.6
Technology	0603005A	11.0	13.5	1.5	0.0	0.0	0.0
Vehicle Systems	DTO Total	13.5	14.9	2.6	0.8	0.7	0.6
GV.06.02.N	0602121N	5.3	4.4	4.0	3.6	3.6	3.6
Power & Auxiliary	DTO Total	5.3	4.4	4.0	3.6	3.6	3.6
GV.07.02.N	0602121N	5.6	4.3	5.1	5.4	5.4	5.4
Hull	0603782N	4.1	6.0	6.0	0.0	0.0	0.0
Systems	DTO Total	9.7	10.3	11.1	5.4	5.4	5.4
GV.08.02.N	0602121N	2.3	2.0	2.1	2.6	2.6	2.6
Integrated	0603792N	7.9	15.9	17.5	14.5	5.0	0.0
Topside	DTO Total	10.2	17.9	19.6	17.1	7.6	2.6
GV.09.01.NE	0602121N	2.2	2.2	2.4	2.5	2.5	2.5
Automation	0603508N	0.0	5.0	7.0	7.0	7.0	7.0
	0602702E	10.9	10.7	0.0	0.0	0.0	0.0
	DTO Total	13.1	17.9	9.4	9.5	9.5	9.5

Figure IV.13. Ground Vehicles and Watercraft Technology Roadmap Resources
TOTALS MAY NOT AGREE DUE TO ROUNDING

DTOs	Program Element	$ in millions					
		FY1996	FY1997	FY1998	FY1999	FY2000	FY2001
GV.10.00.NE	0602121N	3.4	2.9	3.3	3.6	4.1	4.2
Advanced Mach.	0603508N	0.0	0.0	0.0	0.0	0.0	3.0
Truss Support Sys	0603569E	1.8	0.0	0.0	0.0	0.0	0.0
	DTO Total	5.2	2.9	3.3	3.6	4.1	7.2
GV.11.02.N	0602121N	5.8	5.7	6.6	6.0	5.0	5.0
Maneuvering	0603508N	0.0	0.0	4.4	9.4	7.5	5.0
Systems	DTO Total	5.8	5.7	11.0	15.4	12.5	10.0
GV.12.01.N	0602121N	4.3	3.7	4.4	5.1	5.3	5.4
Signature Contr	0603508N	15.1	17.1	1.0	0.0	3.0	3.0
Systems	0603792N	5.0	0.0	0.0	0.0	0.0	0.0
	DTO Total	24.4	20.8	5.4	5.1	8.3	8.4
GV.13.02.N	0602121N	2.4	2.1	2.4	2.5	2.9	3.0
Stuctural Sys	DTO Total	2.4	2.1	2.4	2.5	2.9	3.0
GV.14.07.N	0602633N	11.5	11.5	11.9	12.4	12.7	13.2
UUV Technology							
	DTO Total	11.5	11.5	11.9	12.4	12.7	13.2

Figure IV.13. Ground Vehicles and Watercraft Technology Roadmap Resources

TOTALS MAY NOT AGREE DUE TO ROUNDING

GROUND VEHICLES AND WATERCRAFT ACRONYMS

ADATS	Adjustable Diversity Acoustic Telemetry System
ADCAP	Advanced Capability Torpedo
ADH	Advanced Double Hull
AEMS	Advanced Enclosed Mast/Sensor System
AMC	Army Materiel Command
ARL	Army Research Laboratory
ARO	Army Research Office
ARPA	Advanced Research Projects Agency
ASM	Armored Systems Modernization
ASW	Anti-Submarine Warfare
ATA	Army Technical Architecture
ATD	Advanced Technology Demonstration
ATT	Advanced Tank Technologies
ATT	Anti-Torpedo Torpedo
AWE	Advanced Warfighting Experiment
C3I	Command, Control, Communications and Information
CAC2	Combined Arms Command and Control
CAV	Composite Armored Vehicle
CE	Chemical Energy
CECOM	Communications and Electronics Command
COE	Common Operating Environment
CV	Aircraft Carrier
DDG	Guided Missile Destroyer
DIL	Digital Integration Laboratory
DSI	Distributed Simulation Internet
EFP	Explosively Formed Penetrator
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EME	Electromagnetic Environment
EMEM	Electromagnetic Environment Monitor
EMI	Electromagnetic Interference
FMBT	Future Main Battle Tank
FSV	Future Scout Vehicle
GPS	Global Positioning System
HM&E	Hull, Mechanical, and Electrical
HYDROX	Fuel and oxidizer for half-length torpedo consisting of Hydrogen and Oxygen
ICT	Integrated Concept Team
IPPD	Integrated Product and Process Development
IR	Infrared
IRAD	Independent Research and Development
IUGS	Internetted Unattended Ground Sensors
kbps	kilo-bytes per second
KE	Kinetic Energy
LDUUV	Large Diameter Unmanned Undersea Vehicle
LHT	Lightweight Hybrid Torpedo
LMRS	Long-term Mine Reconnaissance System

LPD	Amphibious Transport Dock
MCM	Mine Countermeasures Ship
MERS	Multifunction Electromagnetic Radiating System
MHC	Mine Hunter Coastal Ship
MK30	ASW Training Target
MK48	Heavyweight Torpedo
NAC	National Automotive Center
NPA	Naval Postgraduate School
NSF	National Science Foundation
NSWC/CD	Naval Surface Warfare Center/Carderock Division
ONR	Office of Naval Research
PEBB	Power Electronic Building Blocks
PMO	Program Management Office
RCS	Radar Cross Section
RSTA	Reconnaissance Surveillance Target Acquisition
RSV	Reconnaissance Scout Vehicle
S&T	Science and Technology
SATCOM	Satellite Communications
SC21	Twenty-First Century Combatant
SDV	Swimmer Delivery Vehicle
SLID	Small Low Cost Intercepter Device
SMI	Soldier Machine Interfaces
SOCOM	Special Operations Command
STW	Synthetic Theater of War
SV	Scout Vehicle
TAP	Technology Area Plan
TD	Technology Demonstration
TRGV	Tactical Robotic Ground Vehicle
URI	University Research Initiative
USCAR	United States Consortium for Automotive Research
USMC	United States Marine Corps
UUV	Unmanned Undersea Vehicle
VETRONICS	Vehicle Electronics
VP	Virtual Prototyping
VSIL	Vetronics Systems Integration Laboratory

V. FY 1997 DEFENSE TECHNOLOGY AREA PLAN FOR MATERIALS/PROCESSES

1. INTRODUCTION

1.1 Definition/Scope

The Materials/Processes Technology Area encompasses the four broad foundational technologies shown in Figure V.1. Materials/Processes underlies virtually all hardware, platform, and infrastructure development and interfaces with most technology areas, particularly Air Platforms; Chemical, Biological Defense, and Nuclear; Ground Vehicles and Watercraft; Sensors and Electronics; Space Platforms; and Weapons.

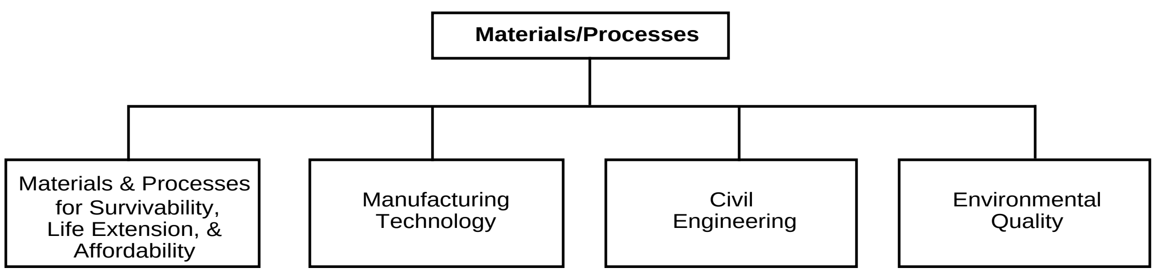


Figure V.1. Planning Structure - Materials/Processes Technology

These four areas have the following general programmatic content:

- **Materials and Processes for Survivability, Life Extension, and Affordability.** Provides enabling materials technologies to ensure the survival of the individual combatant and equipment, assure maximum effectiveness of the force via understanding of the operational situation, and maximize the ability of the force to neutralize hostile threats. Develops materials; such as new corrosion-resistant alloys, coatings, and lubricants; and processes, e.g., corrosion control, fatigue analysis, nondestructive evaluation, and condition-based maintenance, to significantly extend the lives of current and new Defense assets. Furnishes basic materials on which new and upgraded platforms will rely for increased performance, survivability, and longevity at affordable costs.

- **Manufacturing Technology.** Supports force modernization and readiness by focusing on affordability through manufacturing cost reduction, the achievement of large savings in manufacturing design and fabrication lead time, the reduction of scrap and rework costs through integrated design and manufacturing approaches, and streamlined production management. In

particular, emphasis is placed on speeding the transition of leading edge technologies, such as advanced composite materials, metals, and complex electronic systems, out of the laboratory and into fielded weapons systems, utilizing the latest in manufacturing techniques and processes.

- **Civil Engineering.** Supports all aspects necessary for force deployment, protection, and sustainment, including logistics planning and management, amphibious assault and logistics-over-the-shore, base infrastructure, and facilities in the field (from foxholes to fortifications). Of particular military consequence is support for mobility and countermobility, amphibious assault and logistics-over-the-shore.

- **Environmental Quality.** Provides the necessary technologies to comply with and exceed environmental regulations, prevent pollution from Defense facilities and operations, and permit our warfighters to operate in any theater complying with local requirements and with minimal environmental impact. Technologies for both prevention and remediation of pollution are pursued.

See Resource Appendix for funding of this Defense Technology Area.

1.2 Strategic Goals

Materials/Processes technologies fundamentally form the basis to meet all DoD platform, infrastructure, and logistical needs. Continued progress in Materials/Processes is essential in increased affordability, performance, and longevity in DoD systems and operations and, therefore, in meeting all the Joint Chiefs of Staff Warfighting Capabilities. In particular, Materials/Processes addresses the following broad goals:

- Casualty Reduction/Prevention
- Increased Survivability and Decreased Weight of Platforms, Hardware, and Structures
- Significantly Lowered Acquisition and Operations Cost of Systems/Structures
- Extending the Operationally Effective Life of Defense Platforms and Structures
- Greatly Lowered Cycle Times for Weapon System Acquisition and Repair
- Logistic Support for Force Projection from Forward Bases, Over Land, and from the Sea
- Meeting Environmental Quality Regulatory Goals and Pollution-Free Operations

Some key specific transition goals are listed in Figure V.2. A list of acronyms appears at the end of the chapter.

Subarea	Current Baseline	5	Years 10	15
Materials and Processes for Survivability, Life Extension, and Affordability	• GEOSAT, LOSAT • F/A-18E/F, F-22, V-22, B-2, C-17, AH-64A • DDG-51, CVN-73, SSN-21 • M1, M2/M3, LAV. • High Costs of Operating Restrictions for Environmental Security	• GEOSATFO • Aircraft Upgrades, AH-64D • SLEP, CVN-77, LPD-17, NSSN • M1/2/3 Upgrades, Crusader • Environmental Compliance of Defense Industrial Support Systems	• Adv EHF • Aircraft Upgrades, JAST, RAH-66 • SC-21, Post NSSN • Future Scout Vehicle, Crusader Mod • Unencumbered Operations of Ships and Submarines	• HEXSAT • Aircraft Upgrades, ASTOVL • CVX, Far Term Fast Sealift • Future Main Battle Tank • Global Compliance and Non-Polluting DoD Systems
Manufacturing Technology	• Army: Javelin, ITAS/IBAS, TWS, DVE, EFOG-M • Navy: F/A-18C/D, EA-6B, DDG-51, AIM-9R, AEGIS, CVN-73 • Air Force: F-15, F-16, C-17, C-141, AMRAAM, AWACS	• Apache Longbow, HTI, Aviation B-Kit, LRASS3, Stinger Blk II, OICW • LPD-17, CVN-77, SLEP, NSSN, V-22 • F-22, JDAM, JSOW, JASSM, WCM, AMRAAM II	• RAH-66, LOSAT, FMST, BAT P3I, Future Scout Vehicle • SC-21, Post NSSN, JAST, UUV • JAST, SBIT, Tier-3 UAV, JSTARS Upgrade	• Future Main Battle Tank, Miniature Missile, Smart Munitions • CVX, Far Term Fast Sealift, JSA • JSA, Aircraft Upgrades, Next Gen A/S Missile, AWACS II
Civil Engineering	• Conventional Engineering for Structures/ Logistics • Vulnerable Facilities	• 3X Strength Concrete • 5X Effectiveness in Ship to Shore	• 8X Strength Concrete in MilCon • Ground Mobility Simulations • Matls. & Methods to Repair In-Theater Transportation Infrastructures	• 50% Reduction in Construction Labor • Marginal Material Pavements • Survivable Critical Facility
Environmental Quality	• Heavy Metal Electroplating, Volatile Organic Solvents, Cleaning • Wastes and Hazardous Landfills • Costly Pump & Treat Remediation • Restriction in Training to Avoid Unknown Impacts	• 50% Reduction in Hazardous Waste via Material Substitution • 75% Reduction in NOx from JETCs, AGE, & Ships • 90% Reduction in Cost of Fuel Cleanup • Range Scheduling Management for TES	• Replacement of Volatile Organic Paint & Depaint • 90% Reduction in VOC Emissions Production Facilities • Complete In-Situ Destruction of DNAPLs • 75% Reduction in Soil Erosion on Bases & Ranges	• Pollution-Free Paint & Depaint • Zero Pollutant Emissions in Rework/Repair • Complete Restoration of Sites with Ordnance/Heavy Metals • Risk-Based Ecosystem Use Models

Figure V.2. Materials/Processes Technology Transition Opportunities

1.3 Acquisition/Warfighting Needs

All military hardware relies on Materials/Processes for its performance and, indeed, its very existence. Military operations, including low intensity conflict and peacekeeping, critically depend on the dependability of vehicles, systems, and the logistical train. Such systems depend on Materials/Processes to deliver, operate, and protect the warfighter. Space permits few examples here, but worthy of note are the following: the acquisition cost of laser eye protection goggles (or any other hardware) is directly related to the number that can be fielded; the weight of individual systems largely determines the number or sorties needed for delivery; and attrition rates of equipment in peacetime operations depend most sensitively on wear, corrosion, and maintenance costs. The importance of environmental quality is recognized in formal Service/DUSD(ES) requirements.

2. DEFENSE TECHNOLOGY OBJECTIVES (DTOs)

The focus of the Materials/Processes Technology Area efforts is the attainment of twenty identified Defense Technology Objectives (DTO). A listing of DTOs is presented here; the complete statement of these DTOs can be found in Appendix A.

2.1 Materials and Processes for Survivability, Life Extension, and Affordability

MP.01.05.NF	Protective Materials for the Combatant and Combat Systems Against Conventional Weapons
MP.02.05.ANF	Laser Protective Materials for Warfighters and Equipment
MP.03.06.NFE	Materials and Processes to Prolong the Active Life of Aging Systems
MP.04.06.NFE	Materials and Processes for Major Cost Reductions
MP.05.01.NFE	Sensor and Device Materials to Enhance Battlefield Situation Awareness
MP.06.02.ANF	Armament and Ordnance Materials to Reduce Shot Per Kill Ratios
MP.07.06.NF	Materials & Processes for Higher Performance, Affordable Propulsion

2.2 Manufacturing Technology (ManTech)

MP.08.06.E	Affordable Multi-Missile Manufacturing (AM3) ATD
MP.09.06.ANFE	Producible Designs for Affordable Force Modernization
MP.10.06.FE	Interferometric Fiber Optic Gyro (IFOG) Flexible Manufacturing ATD
MP.21.06.ANFES	Affordable Industrial Processes and Practices
MP.22.06.ANFS	Capable Manufacturing Processes
MP.23.06.ANFES	Affordable Short-Lead-Time Repair and Low Volume Production

2.3 Civil Engineering

MP.11.11.A	Mobility, Countermobility, and General Engineering
MP.12.11.N	Logistics Support for Expeditionary Forces and Naval Combatants
MP.13.11.F	Wartime Contingencies and Bare Air Base Operations
MP.14.06.AF	Structures and Fortifications for Force Protection Against Conventional Arms
MP.15.06.FN	Fire Fighting Capabilities for the Protection of Weapon Systems
MP.16.11.AFN	Airfields and Pavements for Force Projection

2.4 Environmental Quality

MP.17.06.ANFED	Hazardous and Toxic Waste Treatment/Destruction for DoD Operations
MP.18.06.AFD	Cleanup of Contaminants
MP.19.06.NFD	Metal Cleaning Processes and Coating Materials
MP.20.06.AFD	Sustainable Land and Airspace Use for Training and Testing

3. TECHNOLOGY DESCRIPTION

3.1 Materials for Survivability, Life Extension, and Affordability

3.1.1 Warfighter Needs

Advanced materials are a basic enabling technology for all DoD systems. Accordingly, they are essential in attaining many if not all of the Joint Warfighting Capability Objectives.

Survivability. Specifically, under the objective for Military Operations in Urban Terrain, by 2001, a 40% weight reduction will be realized in helmets and vests for protection against small arms projectiles and fragments, along with face shield and window protection at 30% weight reduction. Similar weight reduction will also be achievable in vehicles through the substitution of titanium armor for steel. Lastly, in the area of survivability, by 2000, the system damage threshold of electro-optical sensors to both short pulse and long pulse fixed wavelength laser threats will be improved by 1000X, while maintaining optical transmission greater than 90%.

Lethality/Surveillance. In the Precision Strike objective, increased lethality will be possible through tungsten based anti-armor penetrators. This objective will be further enhanced through advances in IR/radar sensor materials that will yield a 50% increase in detection range and a two fold improvement in target acquisition and tracking. These advances plus the epitaxial growth of defect-free semiconductors will provide a 3-fold improvement in space surveillance and secure spacecraft laser communication, factors that are critical to the Joint Theater Missile Defense objective.

Life Extension. While none of the Joint Warfighting Objectives address life extension specifically, the limited number of new systems being procured, along with Chairman's goal of maintaining force structure, demand that technology be developed to ensure the extended life of current military systems with no degradation, and potential improvements in warfighting capability. The KC-135 tanker fleet is now anticipated to be kept in service until 2040. This example is typical of the life extension being contemplated for other aircraft, ships, armor vehicles, trucks, and essentially all systems needed to ensure military superiority. The payoff potential for effective life extension programs can be as large as $50B per year.

Affordability. Reduced costs are significant factors in several of the Joint Warfighting Capability Objectives, both through reductions in acquisition costs and supportability costs. For example the Real time Logistics Control objective anticipates improvements in deployment/sustainment through ceramic engines, unlimited life expectancy batteries, and low cost UAV airframes. The latter is also a goal of the Joint Countermine objective. Examples of cost reduction through material substitution include reskinning the wing of the RC-135 using lightweight metallic alloys and organic and metal composites to extend the life of this reconnaissance asset, as well as extent the range by 30% with an attendant increase in loiter capability. Similarly, low cost composites process techniques have been demonstrated in a retrofit of the F-117 fighter aircraft trailing edge components resulting in 50% reduced acquisition cost and a three-fold extension in component life. The use of high strength, low alloy (HSLA) steel in place of high yield (HY) steels has saved over $135M during the past ten years in surface ship construction. Future ship and submarine construction cost savings via HSLA are projected to be at least $30M per year.

3.1.2 Materials and Processes for Survivability, Life Extension, and Affordability Overview

3.1.2.1 Goals and Timeframes

TIME	AREA	GOALS
2000	Ballistic Protection	• 30-40% weight reduction for small arms and fragment protection
	Laser Protection	• Optimization and fielding of eye protection for the most probable fixed battlefield laser threats
	Transducers	• 90% reduction in submarine/ship acoustic radiation via active control
	Infrared Domes	• 200% improvement in rain and dust durability for supersonic IRST sensor
	Electromagnetic Sensors	• 50% increase in infrared (IR) sensing range, twofold improvement in target identification
	Life Extension Reliability	• Twofold increase in aircraft paint system lifetime with reduced chromates and VCOs • NDE Methods for flaw assessment, and detection of cracks under installed fasteners • 50% reduction in corrosion-initiated flaws resulting in 40% life-cycle component cost savings

TIME	AREA	GOALS
	Affordable Processing	• 90% reduction in small lot (10-100) component costs via intelligent and flexible manufacturing
	Organic - Matrix Composite (OMC)	• 10-20% cost reduction via automated manufacturing and reduced parts count
	Low Cost Titanium (Ti)	• 40% weight reduction and immunity to corrosion via substitution of $7/lb structural titanium alloys (Ti) for steel
	Engine Materials	• 40% component weight savings via substitution of intermetallics for nickel superalloys
2005	Ballistic Protection	• 20-30% weight reduction in hardened shelters for personnel
	Low Observability	• Independently controllable emissivity/reflectivity coatings
	Infrared Domes	• Develop affordable processes for growth and polishing of diamond domes
	Electromagnetic Sensors	• 50% improved detection by superconducting magnetic sensors
	Life Extension	• Wear monitoring sensors for life management with 30% reduction in ship maintenance hours • 60% life increase for helicopter replacement parts via increased corrosion and fatigue resistance
	Reliability	• Nondestructive evaluation (NDE) detection of hidden corrosion in aircraft-25% Operation and Support (O&S) cost savings
	Affordable Processing	• 40% savings via biotech processing industry to provide water-based, low energy, environmentally compatible manufacturing • Co-curing technology to reduce weight by 10% in composite aircraft structure
	OMC	• 25-50% weight reduction in ship superstructures with lowered signature
	Ti	• 50% reduction in welding and machining costs
	Engine Materials	• 30-50% reduction in fuel consumption and 50% less nitrogen oxides via ceramic components
2010	Low Observability	• Develop adaptive coatings/systems that respond automatically to background and threats
	Transducer	• Provide full active vibration control of ship systems, virtually eliminating acoustic signature
	Electromagnetic Sensor	• Affordable, reproducible SiC for 350-500°C electronics • Provide condition-based maintenance for 80% reduction in mechanical flight mishaps
	Life Extension	• 40% reduction in rework costs associated with wear via advanced coatings
	Reliability	• 50% reduction in the cost of elastomeric components/materials via electroset processing and control of properties
	Affordable Processing	• 60% cost reduction in production of welded platforms via computer feedback control with integrated nondestructive inspection (NDI) acceptance system
	OMC	• Complete field repairability of composite structures
	Engine Materials	• Reliable joining and inspection of ceramics and metals for hybrid components

3.1.2.2 Major Technical Challenges. Improve survivability of personnel and systems. The principal challenges in making ultralight personnel protection are to reduce the weight and cost of ceramic components, increase ballistic performance, and optimize ceramic-composite systems performance. The major challenge involved in protecting eyes and sensors from battlefield lasers is to develop materials and concepts for components that extend the range of protection, maximize optical transmission, and permit tuning of rejection wavelengths to defend against a wide range of laser threats. The major challenges for signature control are cost reduction (which includes acquisition, inspection and repair costs), weight reduction, and the development of materials systems and related processing technology for "building in" low observability into structures rather then adding it on.

Enhanced situational awareness. Major challenges are the development of materials and material concepts for improved sensors (sensitivity and selectivity) and for improved data acquisition, analyses, and transmission systems (radiation hard). Meeting these challenges will necessitate the development of improved processing techniques to eliminate and/or control the microscopic defects in bulk and epitaxially grown semiconducting, superconducting ferroelectrics, piezoelectric, and magnetic materials. Improved processing techniques will increase the production yield while reducing the size and costs of information gathering systems.

Increase lethality and pinpoint accuracy. The major challenge involved in extending the durability of IR domes and windows for high-speed flight through rain and dust is the development of efficient, low-cost diamond deposition and polishing techniques.

Extended service life and enhance reliability. The major technical challenge of reliability-centered maintenance is to develop technologies and methodologies such as NDE that allow effective implementation and integration of time-directed and condition-based maintenance of mechanical equipment on all DoD platforms. Challenges in NDE encompass the development and application of highly accurate, reliable, and cost-effective methods, equipment, instrumentation, and sensors needed to enhance processing, reduce costs, and verify the quality of advanced materials systems. Also, current DoD corrosion-resistant coatings have limited service lives and do not comply with emerging environmental regulations. Long-life, environmentally compatible coatings must be developed using high-solids, waterborne, and powdered polymers. There is also a need for improved elastomers and seals, including lightweight aircraft sealants that reduce fuel leakage, decoupling elastomeric coatings that reduce vibrations in ships and submarines, and acoustically transparent seals for sonar arrays. The performance of fluids and lubricants must be improved through enhancements in durability, service life, and resistance to fire and corrosion. Cost-effective materials processing methods must be developed that assure repodiucibility and material quality.

Affordable systems and operations. The challenge in reducing construction costs for ships and submarines using steel alloys is to develop affordable mill processing and improved fabrication and welding technologies. The challenge in the development of and transition to lightweight aluminum alloys (e.g., aluminum-lithium) is to achieve uniform mechanical properties in all directions. For tailored OMCs, the challenge is to develop systems that simultaneously meet the structural, electromagnetic, signature, and durability requirements of military systems. Additionally, for OMCs the challenge in

achieving major cost reductions is to develop materials and techniques for processing at low temperatures (150°F) and pressures (i.e., non-autoclave methods). The challenge in developing new and improved lightweight titanium alloys and high-temperature intermetallic materials is to achieve acceptable mechanical properties coupled with resistance to the environment.

High-temperature propulsion and structural materials. Challenges include improving the properties of superalloy disks for turbine engines, now limited in terms of their resistance to creep in the rim and their burst strength in the bore; and high-temperature advanced intermetallic materials and composites, which currently lack balanced engineering properties.

3.1.2.3 Related Federal and Private Sector Efforts. With support from the Departments of Commerce (DOC) and Energy (DOE) and agencies, such as, the Federal Aviation Administration (FAA) and the National Institutes of Health, various electronic and transducer technologies are being transferred to the automotive, aviation, and medical fields. These include collision-avoidance radar, high-speed optical switching and computing components, superconducting motors, methods for detecting environmental pollutants, and medical imaging devices. The DOC and the abrasives industry are supporting basic research on the physics and growth of diamond. The National Aeronautics and Space Administration (NASA), DOE laboratories, the DOC's National Institute of Standards and Technology, the FAA, and supporting industries are involved in related efforts in aging aircraft, service life extension, reliability, and cost reduction, with collaboration occurring at the program level. The Department of Transportation's highway infrastructure renovation program depends heavily on advances in defense technologies such as NDE and composite materials. Weight reduction and increased quality are major objectives in virtually all vehicle and aircraft research and development programs. Two DOE programs, Continuous Fiber Ceramic Composites and Ceramic-Matrix Composite Multi-megawatt Turbines, are based on recent defense technologies. Increasing use of advanced materials in civilian applications will reduce the costs of defense-specific uses.

3.1.3 S&T Investment Strategy

3.1.3.1 Technology Demonstrations. There are three technology demonstration (TD) programs in this subarea. The objectives of the **Laser Protection TD** are to test and validate day/night protective devices or schemes that are compatible with cockpit displays and life-support equipment to provide full retinal protection, and to validate laser protection schemes in actual electro-optical sensor systems and developmental breadboards for fixed-wavelength threats (near term) and agile wavelength threats (long term).

The **Advanced Nondestructive Evaluation TD** is dedicated to increasing significantly the accuracy, reliability, and affordability of early detection of safety and service-life-limiting defects and deterioration damage (e.g., minor but widespread fatigue damage and hidden corrosion) particularly in aging weapons systems. Advances include high-speed semi-automated, noncontact scanning of large surface areas, real-time in-situ monitoring of structural integrity-sensitive locations based on the use of new probe/sensor concepts and high-speed data processing, and the application of accurate NDE characterization and damage growth prediction processes to forecast components' remaining safe, economical life.

The **Electrochemical Power Sources TD** focuses on extending the life of electrochemical power sources (i.e., rechargeable batteries and fuel cells) for a wide range of portable electronic equipment. Methods will be developed for fully automated production and rapid prototyping of rechargeable batteries that provide three times the energy per weight/volume of existing systems, with deep discharge and elimination of self discharge. Simplified fuel cell technology will enable the use of military (logistics) fuels for portable power with a twofold improvement in efficiency over existing generator systems and reductions in pollution and noise.

3.1.3.2 Technology Development. To achieve the necessary advances in materials and reproducible low-cost processing technologies, focused time-phased programs are directed at modeling of the functional physics, improving physical properties, and reducing the cost and weight of systems. Programs include the synthesis, processing, and characterization of materials and sub-scale demonstration components. Topics include:

- Advanced composite, ceramic, and metallic armor materials to protect the individual combatant and combat systems against conventional weapons.
- Advanced materials and concepts (e.g., absorbing dyes, filters, optical switches and limiters, and nonlinear optical elements) for protection of warfighters and equipment from laser threats.
- Sensor and device materials (e.g., semiconductors, superconductors, ferroelectrics, piezoceramics, and magnetic and nonlinear optical materials) that will enable significant increases in information gathering, analysis, and dissemination to improve battlefield situation awareness.
- Signature control materials, including specialty coatings and absorbers, to minimize the IR, visual, radar, acoustic, and magnetic signatures of weapons systems.
- Electromagnetic domes/windows with durable coatings to minimize rain/dust damage, and tungsten-based anti-armor penetrators for enhanced weapon delivery and lethality.
- Advanced NDE technology for characterizing materials and structures, supporting manufacturing requirements, and providing the capability to detect a wide variety of in-service and aging system problems, including hidden corrosion, cracks under installed fasteners, and flaws in welded joints and critical components (e.g., turbine blades).
- Advanced coatings for ground equipment, ships, submarines, and aircraft that meet environmental regulations, extend system lifetimes, and reduce overall maintenance costs.
- Advanced battery materials having higher energy/density and extended service life.

- Improved hydraulic fluids, engine coolants, turbine engine lubricants, and greases for all DoD vehicles, ships, and aircraft.
- Advanced tools such as diagnostic algorithms, prognostic methods, and robust sensors that can be integrated into a variety of systems to enhance reliability.
- Industrial "artificial intelligence" methods for affordable process control and pattern recognition as well as other critical fabrication and manufacturing processes.
- Metallic structural materials, including ferrous-based alloys (steels), non-ferrous alloys (low cost titanium), and MMCs having lighter weight and lower cost.
- Polymer composite structural materials, including thermoset and thermoplastic matrix composites for aircraft structure, ship bulkhead and superstructure (low signature), turbine engine duct/case and spacecraft structure.
- High-temperature metals and intermetallic materials, including titanium-based alloys, superalloys, and advanced intermetallics for turbine and rocket engine components.
- Ceramics and carbon-carbon composites, including monolithic ceramics and CMCs for rocket engines, spacecraft solid and liquid engines and spacecraft truss and radiation assemblies.

3.1.3.3 Basic Research. Many areas of basic research are relevant to this subarea. Research on new metals and ceramics and associated processes has increased the predictive capability and multi-hit tolerance of lightweight armor. Materials modeling and simulation of electronic interactions and non-linear optical properties may enable development of materials that protect eyes and sensors from laser damage. Understanding of piezoelectric and magnetic materials will enable the development of highly sensitive sensors for awareness and mine detection. Basic research also is crucial to understanding of degradative processes (e.g., corrosion, wear, fatigue) that limit the service life of DoD systems. Advances in sensors, diagnostics, and information storage and analysis are needed to make condition-based maintenance and high-cycle fatigue prediction and control a reality. New materials for lubricants and corrosion control and anti-fouling coatings are expected to emerge from surface chemistry and applied materials research. Basic research in materials, mechanics, and data analysis will enhance the sensitivity of NDE methods as well as their ruggedness. Basic research continues to produce novel means of extending the life and increasing the energy density of batteries and fuel cells for DoD electronics and power systems. Micro-alloyed steels are being characterized and scientifically designed for use in weapons systems. High-temperature and structural carbon fibers are being synthesized continuously and combined with new chemical resins properties of the resulting composites can be defined more precisely due to advances in surface science and methods for evaluation at the atomic level Basic Research on intermetallic alloys has improved the ductility of these brittle systems, and mechanical design research has made it possible to design even rotating systems with brittle metallic and ceramic materials.

3.2 Manufacturing Technology

3.2.1 Warfighter Needs

Force Readiness and Force Modernization are fundamental needs of the warfighter. Defense budget reductions in recent years have created situations where the needs for both readiness and modernization could not be met simultaneously and one or the other has been sacrificed. In this austere environment, affordability and rapid cycle times for acquisition of new systems and repair of existing systems are key to ensuring that the United States maintains an appropriate mix of systems and forces that are ready to respond to the defense missions of the future. Warfighters need a responsive industrial base with advanced manufacturing technologies and processes that reduce costs and lead times at every level -- in the design process, in development, in production, and in the support of fielded systems. Those same issues, affordability and cycle time reduction, are the predominant aims of the Manufacturing Technology (ManTech) subarea. World-class commercial companies have demonstrated overall product development and production cost reductions as well as cycle time reductions on the order of 50%. Despite the major differences in products and customer requirements, cost and cycle time savings in that same range are feasible for military products as well.

Affordability. Sharply reduced acquisition and support costs that permit the purchase of more systems or spare parts or the insertion of more new technology into existing systems for the same budget level have obvious implications for both readiness and modernization.

Cycle Time. Typical development cycles for new major weapon systems currently stretch to more than ten years while new generations of electronics technology arrive every three or four years. This mismatch makes fielding obsolete equipment in our latest weapon systems almost unavoidable. A capability for rapid system acquisition or technology insertion would permit the fielding of today's technology -- with rapid upgrades possible as threats or missions changed over time. Rapid repair and production cycles would allow quicker response to the changing needs of the force. Short cycle times almost invariably create significant cost reductions and will also allow other costs (e.g., purchase of spare parts or development of new systems) to be deferred to future budget years. Again, the implications for readiness and modernization are clear.

Improvement not spontaneous. Despite the powerful influence of DoD budget reductions, sweeping cost reductions and cycle time improvements will not occur spontaneously. Traditional defense suppliers, often shielded from the forces of competition based on price and speed to market, do not always have efficient practices and processes compared to the world's leading commercial firms. Nor do the traditional DoD contracting and incentives approaches provide a profit motive to improve. World-class commercial manufacturers have focused on systematic elimination of inefficiency and non-value-added cost in all areas. In addition, there are militarily important technology areas where commercial rather than defense firms are the technology leaders. ManTech is working to create major shifts in the cost and speed with which military products are developed, produced and repaired by benchmarking the best practices in the industrial world and fostering their widespread implementation. ManTech is working to eliminate barriers which impede military access to affordable commercial products and production of military goods on efficient commercial production lines.

Flexibility. The days of mass production are largely gone in the commercial world. Commercial companies have learned how to be flexible in their approach to manufacturing so as to be able to add custom product features, mix products on production lines, and affordably make ever smaller lots of products to respond to changing needs of their customers. Warfighters require that same affordable manufacturing flexibility. It is very efficient for the DoD to make the maximum use of commercial processes and products to meet defense needs. Nevertheless, the development and production methods that are successful in the commercial world often need significant adaptation and demonstration to assure that they are robust enough to deal effectively with the need for superior defense products.

Rapid transition of defense-essential or defense-unique technologies. There are critical areas where defense-essential products have no commercial counterpart (e.g., munitions, traveling wave tubes, obsolete electronic components) or where the defense application is so far ahead of potential commercial applications that DoD must invest to assure that key products and process are available to support readiness and modernization (e.g., thrust vectoring nozzles for short takeoff and landing aircraft, Interferometric Fiber Optic Gyros for navigation). Therefore ManTech is also investing in developing manufacturing processes and capability to support defense-essential product technologies. Heavy emphasis is placed on maturing defense-essential technologies emerging from development to foster rapid, low-risk transition of advanced technology out of the laboratory and into new systems or to extend the useful life of existing military systems. Thus **ManTech has a strong and direct influence on the readiness and modernization of the forces available to the warfighter**.

3.2.2 Manufacturing Technology Overview

3.2.2.1 Goals and Timeframes

TIME	AREA	GOALS
2000	Capable Processes for Low-Risk Fielding of Advanced Defense-Essential Technologies	• Widespread implementation of 6-Sigma methodology • Reduce costs to $700/axis for tactical grade IFOG • Reduce costs to $1500/axis for navigation grade IFOG • Demo 50% reduction in composite material fabrication costs
	Affordable Military Capability via the World's Best Industrial Capabilities	• Missile component demos of 25% cost and time savings • Demo 30-50% avionics cost reductions using commercial line • Demo 30-50% cost reduction for aircraft parts & subsystems • Demo 25% reduction in acquisition time for ships
	Producible Designs for Affordable Force Modernization	• Demo 40% reduction in producibility design changes • Demo 25% reduction in time to incorporate design changes • Demo 95% first-pass yields for critical electronic components

TIME	AREA	GOALS
	Affordable, Short-Lead-Time Production & Repair at Low Volume	• Demo 30% reduction in supplier management costs, 75% reduction in supplier contracting time, and 50% reduction in supplier lead times • Demo integrated scheduling for several military products in simultaneous low-volume production • Demo 80% reduction in lead-time for work order release
2005	Capable Processes for Low-Risk Fielding of Advanced Defense-Essential Technologies	• Demo 6-sigma for engine turbine and composite structure repair processes • Demo production-ready process variability control for military-unique chips, modules, boards and near net shape parts • Demo green board design tools and processes • Demo continued IFOG cost reduction slope of 10%/axis/yr • Demo 75% cost reduction for optics components
	Producible Designs for Affordable Force Modernization	• Demo 80% drop in design changes for producibility • Demo 30% reduction in production transition cycle time • Demo methods to ensure 6-sigma capability at design release • Demo accurate mfg cost estimating tools in preliminary design • 10X more design alternatives in 1/2 time for seekers & sensors
	Affordable, Short-Lead-Time Production & Repair at Low Volume	• Demo 90% reduction in time to reschedule compete supply chain • Routine use of direct vendor delivery in production and repair • Demo 80% reduction in in-process inventory-mech. subsystem • Demo 40% reduction in in-process inventory--repair facilities
2010	Capable Processes for Low-Risk Fielding of Advanced Defense-Essential Technologies	• Green board design tools and processes fully deployed • Six-Sigma capability for military-unique digital and analog chips • Demo 5X better yield in growth and polishing diamond IR domes
	Affordable Military Capability via the World's Best Industrial Capabilities	• Demo 80% cost reduction in high temp IHPTET materials • Demo 50% reduction in design and qualification time for mechanical and electronic subsystems
	Affordable, Short-Lead-Time Production & Repair at Low Volume	• Demo 80% reduction in in-process inventory in repair facilities • Demo 60% reduction in production cycle time for complex electromechanical assemblies

3.2.2.2 Major Technical Challenges - Improve Affordability and Cycle-Time for Military Product. Challenges include demonstrating the effectiveness of the new/improved manufacturing or repair processes on defense-essential products in realistic production conditions to validate cost and capability data and speed their acceptance by industry and product centers; rapidly developing, validating and deploying

tools and methods that can bring 50% reductions in design and development cost and cycle time in a military product environment that demands rapid insertion of leading edge technologies; rapidly developing, validating and deploying factory and business processes and practices that can reduce production and repair costs and cycle times on the order of 50% from current levels in an environment where production runs are rapidly becoming shorter, where the supplier base is rapidly shrinking and where reparable assets are increasingly scarce.

Reduce the Risk and Cycle Time to Field Defense-Essential Advanced Technology. Challenges include developing, refining and characterizing manufacturing processes for leading edge superiority technologies just emerging from the laboratories that don't have market forces to speed their maturation (e.g., thrust vectoring nozzles for aircraft, Interferometric Fiber Optic Gyros for navigation) or to support defense-unique products that have no commercial counterpart (e.g., munitions, Traveling Wave Tubes, specialized explosives and propellants, obsolete electronic components). Designers of defense-essential products require mature processes that will have sufficient cost and capability data to support a 6-Sigma approach to design so that the latest technology can be incorporated with reduced risk to cost, schedule and system performance. Reliable process capability and cost information must be made available to designers in such a way as to promote confident and affordable incorporation of new technology options in new product designs and systems upgrades. Promoting the incorporation of Integrated Product/Process Development (IPPD) into the military supplier network is required to achieve significant cycle-time reductions from design through first time insertion and achieve of predictable and affordable first-time process yield.

3.2.2.3 Related Federal and Private Sector Efforts. The ManTech subarea is actively leveraging funding and related efforts from other federal and private sector sources to advance the area's affordability and speed goals. The objective to assure that ManTech only fully funds those things which are defense-essential and beyond the normal risk of industry. The Department of Commerce and Service acquisition programs have currently committed in excess of $20M to be expended between FY 95-98 on current ManTech programs. In addition, the Departments of Commerce and Energy and the National Science Foundation sponsor between $10-20M per year in related work in electromechanical design and manufacturing. The individual Service laboratories and the National Laboratories also provide crucial feed technologies into to this subarea's technology base. National and international standards efforts are important to the goals of ManTech as are the deployment efforts managed by NIST. Most of ManTech's efforts build directly on private sector products, practices, processes and lessons-learned are the result of many years and many dollars of investment by private industry. One example of direct private sector commitments to ManTech efforts builds on an earlier 5-year, $5M assessment by MIT of the worldwide automotive industry (International Motor Vehicle Program). During FY 95-98, for instance, aerospace industry companies will contribute over $2M as part of the Lean Aircraft Consortium and between FY 96-98 another $7.5M as part of the Lean Implementation Initiative. Other types of private sector commitments include corporate funded travel and data gathering in support of active projects, as well as extensive capital investments companies make to participate in pilot programs as well as in implementing program results.

3.2.2.4 Basic Research. ManTech relies on continuing advances in a broad spectrum of basic research. Examples include sensors, metrology, and microelectromechanical systems for real-time process feedback and control, innovative

material processing concepts, new chemical processes (especially to reduce environmental effects), robotics, knowledge representation, and modeling and simulation in a broad sense, from product and process physics to queuing theory. These research areas are becoming even more important as defense production quantities decline, and first item quality or time-to-field/fleet becomes the key affordability.

3.2.3 Mantech Investment Strategy. ManTech's overall investment strategy recognizes that a relatively small investment can allow DoD to leverage the billions of dollars that commercial industry is spending in striving to excel in world-wide competition. Many of the best methods, products, processes and capabilities that have emerged from that competition can be adapted to develop and produce military goods. Considerable ManTech investment is focused on demonstrating the effectiveness and benefits translation/adaptation of commercial approaches in every key industry segment and product area and fostering the implementation of the results. However, there are some defense-essential technology areas where market forces are not available to create mature manufacturing processes to support low-risk military product development and production. ManTech makes a significant investments in these areas (e.g., munitions, obsolete electronics, IFOG's, TWT's) to assure that these technologies are affordable and available to support new and existing military needs. It is ManTech policy to require tailored cost-sharing by industry participating in ManTech programs. The extent of the cost-sharing is directly proportional to the near-term benefits companies receive and inversely proportional to the level of business risk.

3.2.3.1 Technology Demonstrations. ManTech contains two programs formally recognized as "Advanced Technology Demonstration Programs". They are described in **DTO-MP.10.06 Affordable Multi-Missile Manufacturing (AM3) ATD** and **DTO-MP.08.06 IFOG Flexible Manufacturing ATD.** ManTech programs typically have technology demonstrations as a key objective. Examples from current ManTech programs include:

- Military avionics from an automotive electronics production line (50% cost savings)
- Military aircraft structure using commercial practices and processes (50% cost reduction)
- Cost reductions in composites engine duct structures (50%)
- Cost and cycle time reductions for machining precision aspherical optical lenses (30-50%)
- Integrated electronic board and module test information libraries to generate test source code
- Integrated scheduling throughout a mechanical product supply chain by adapting commercial tools (90% reduction in reschedule time)
- The balance of ManTech technology objectives are described in DTOs MP.21.06, MP.22.06, MP.23.06, and MP.09.06

3.2.3.2 Technology Development. ManTech encourages teaming of university and industry research organizations, defense contractors, and technology vendors to

ensure insertion paths for new technologies. The largest ManTech investments in technology development are targeted on maturing advanced military-essential technologies emerging from 6.2 and 6.3 development to accelerate and reduce the risk of their transition into military products. Examples include:

- Improved yield for multiple bandgap solar cell manufacturing (50%)
- Qualify polymeric sabots for 25 mm M919
- Laser processing technology for low-cost powdered titanium structural members
- Technology for composite armored vehicles
- Fiber Placement for High Performance Airframe structures
- Low-volume Silicon wafer process for VLSI digital parts
- Staring-class dewar production processes

3.3 Civil Engineering

3.3.1 Warfighter Needs

The Civil Engineering subarea directly supports emerging warfighter requirements by providing technologies for force deployment, employment, protection, and sustainment. These technologies are critical to strategic, operational, and tactical missions in all climatic and geographical areas. Six high-priority requirements are addressed. **Mission planning and execution technologies** that are both faster and less manpower-intensive than current systems are being developed for mobility/countermobility (M/CM), survivability, and general engineering (G-ENG) missions. The C/MC/G-ENG analytical software will be integrated into command/control architectures. **Ship cargo discharge concepts and operational systems** to enable rapid transfer of cargo to shore from Amphibious Assault and Strategic Sealift ships in higher sea states and from longer standoff distances than currently possible, so that operational availability for regions such as the Far East can be increased from 15 to 25 days per month. **Bare airbases** are being designed with mobile, easily deployable facilities to enable increased numbers of sorties from forward locations, very rapid reaction times, and reduced deployment costs. **Force protection technologies** (e.g., foxholes, fixed facilities) are being designed and improved to defend against weapon threats ranging from small arms to terrorist weapons to advanced conventional weapons with multi-spectral sensor capabilities. Relevant innovations include battlefield protective fortifications, simplified vulnerability/survivability assessments, and facility retrofits and designs to counter weapons threats. **Fire fighting agents and equipment** are being developed to protect weapon systems, critical facilities, munitions and fuel stores, and personnel in an effort to reduce system damage and casualties resulting from fires and accelerate reconstitution of warfighting capabilities. **Pavement design, repair, and material criteria** are under development to ensure reliable support for future-generation aircraft and vehicles used in military operations.

3.3.2 Overview

3.3.2.1 Goals and Timeframes

By 1997	• Lightweight, low-volume deployable power generator • Global near real-time mobility modeling and knowledge based obstacle planning with reliability quantification • Increase effectiveness of biodegradable fire fighting foam
By 1998	• Pavement design and repair systems using local materials and modified pavement binders • Minimize shipping container marshaling by increased contents visibility, saving up to $150M per operation • Simplified survivability analysis procedure for field fortifications • Camouflage materials and lightweight material revetments for fortifications/aviation asset protection
By 1999	• Lighter mats for repair/expanding aircraft operating surfaces • Increase operational availability of ship discharge lighterage by 67%, and increase capacity by 300%
By 2001	• Develop very high strength constructable concrete for hardened structures • Demonstrate use of light-weight, components for modular construction of protective structures • Develop library of material models for conventional weapons effects code development • Assessment and installation technologies to reduce Elevated Causeway installation time from 9 to 7 days • Superconductive generator for bare base applications • Reduce firefighter heat stress by 50% and improve training by 90% using virtual reality
By 2002	• Develop pavement design and repair systems for new aircraft using smart materials. • Provide materials/methods for worldwide construction with limited resources • Provide technologies to rapidly assess/repair/upgrade bridge structures • Stealth shelter technologies for low visibility Bare Base Operations
By 2005	• Reduce infrastructure acquisition, maintenance and repair costs by 20% of 1990 • Reduce facilities energy consumption by 30% of 1985 • Fire fighting vehicle response improved by 75% with active suspension and forward looking IR
By 2006	• Validate survivability/vulnerability assessment model that includes camouflage concealment detection measures • Self erecting air-mobile shelters, reducing time and manpower • Advanced fuel cell power generation for Bare Bases • Provide common representation of M/CM/G-ENG in C/C architecture with improved throughput capabilities

3.3.2.2 Major Technical Challenges. The major technical challenges include development of lightweight, high-strength, high-ductility and/or innovative adaptive construction materials and criteria; characterization of nonlinear, viscoelastic, viscoplastic material response under dynamic loading (e.g., projectile penetration, explosive detonation, vehicle movement, and breakwater interaction with waves); development of three-dimensional, coupled analytical software that replicates nonlinear material behavior for use in accurate assessment of mobility and structural response;

development of innovative construction concepts for mobile military operations; and advancement of understanding of the physics of fire and extinguishing mechanisms.

3.3.2.3 Related Federal and Private Sector Efforts. The 1994 Laboratory Infrastructure Capability Study concluded that DoD has unique civil engineering research and development (R&D) programs, execution capabilities, and supporting facilities, and that the U.S. construction industry cannot provide the civil engineering technologies required by DoD. The study report stated: "The DoD civil engineering function currently has a very high percentage of in-house R&D expertise. The Panel proposes that the Service engineering labs be greatly expanded and used as a springboard for building a broad-based Government-Industry-Academic applied research effort in this technology area." The unique nature of DoD's civil engineering S&T capabilities is reflected by the fact that government agencies come to DoD laboratories to perform research worth over $100 million (equivalent to DoD S&T) each year. DoD laboratories accept only reimbursable work that complements their own capabilities and does not interfere with their DoD S&T responsibilities.

3.3.3 S&T Investment Strategy

3.3.3.1 Technology Demonstrations. Twelve technology demonstrations (TDs) and advanced technology demonstrations (ATDs) are planned in this subarea. **DTO-MP.11: Total Distribution ATD** will describe and evaluate transportation infrastructure within a theater of operation (TO) and rapidly assess changing priorities, evaluate fleet mixes, and integrate unit/equipment arrival times. **Mobility & Survivability TD** will integrate knowledge and physics-based algorithms using a common infrastructure for data structure, the graphic information system, and mobility algorithms to transform data into usable CM and survivability information. **Logistics Over-the Shore TD** will demonstrate the feasibility of an innovative rapidly installed breakwater system (RIBS) capable of reducing local sea-state conditions from waves 3 feet high to 2. **DTO-MP.12: Amphibious Cargo Beaching Lighter ATD** will demonstrate advanced concepts for open-sea connectors and large, highly seaworthy configurations that will increase operational availability for projected low- and medium-intensity conflicts from 15 to 25 days per month in high sea-state regions while reducing in-water assembly time from 5 to 2 hours and increasing cargo-carrying capacity from 1 Abrams tank to 3. **Waterfront Structures Repair and Upgrade ATD** will integrate high-payoff structural diagnostics and modeling with high-performance materials and corrosion-retarding techniques to extend the service life of existing waterfront facilities and upgrade them to satisfy new mission requirements. Repair durability will be increased from 3 to 15 years and the cost of new pier upgrade alternatives will drop from about $30 million to about $5 million.

DTO-MP.13: New Family of Portable Shelters ATD will demonstrate advanced composite panels for use with the prototype Modular Erectable Rigid Wall Shelter (MERWS). The modified MERWS will be substantially lighter than the existing Bare Base shelter and more energy efficient. **Lightweight Deployable Power Generator ATD** will demonstrate a prototype advanced lightweight generator (120 kilowatts) with motor/generator sets that are 40 percent smaller and 50 percent lighter than current components. This technology will reduce significantly the airlift and logistics support required for bare base deployments. **DTO-MP.14: Simplified Survivability Analysis TD**, which is included within the mobility and survivability battlefield operating system of the Army's Battle Command System, will be demonstrated at Prairie Warrior 96 and 97 and Task Force XXI Advanced Warfighting

Experiment. **DTO-MP.15: Advanced Training System TD** will demonstrate a virtual reality firefighter training system that will improve significantly the effectiveness and safety of firefighter training, thereby greatly reducing casualties and damage to weapons systems from fires. **Poor Visibility Emergency Response System ATD** will demonstrate an all-weather, day-and-night crash and fire rescue capability that will enable effective rescue response in inclement weather, redressing a current DoD deficiency. **DTO-MP.16: Pavement Material TD** will demonstrate material characterization, design, and repair systems through laboratory testing and field evaluations, to verify design system criteria for the use of "smart" materials, local materials (which may not be the best type or quality), and modified pavement binders. **Expedient Surfaces TD** involves field evaluations of innovative surface materials (e.g., geotextile mats) and installation procedures to verify reductions in construction time and the capability to provide service for military aircraft and vehicles.

3.3.3.2 Technology Development. Many of the emerging technologies in this subarea are candidates for future TDs and ATDs. Technologies under development include: **DTO-MP.11: Countermobility Technologies** will provide knowledge-based obstacle planning, techniques, and equipment used for realistic CM engineering using obstacle planner software, employment options, and resourcing. **DTO-MP.11: Mobility Technologies** will provide accurate, near-real-time accurate mobility assessments using high-resolution, high-fidelity, all-weather mobility models; worldwide, high-resolution mobility data; and common representation of M/CM. **DTO-MP.11: Transportation Infrastructure Assessment Technologies** will provide criteria to assess, maintain, repair, upgrade, and construct TO transportation networks that encompass the use of expedient surfacing materials and RIBS for improved logistics throughput. **DTO-MP.12: Amphibious Logistics Technologies** will extend ship-to-shore pumping of fuel from standoff distances of 5,000 to 20,000 feet, new packaging concepts will reduce shipping platform needs by 30 percent, and ship-to-shore batch liquid/fuel delivery systems will enable execution of Marine Corps' Operational Maneuver from the Sea operations. Emerging waterfront infrastructure technologies include modeling capabilities, such as to Wide Aperture Arrays, that can help reduce berthing damage to ships in ports.

DTO-MP.13: Composite Materials will be integrated into panels and deployment approaches for transportable matting for aircraft runways. Performance testing will simulates aircraft traffic on a variety of subgrades. A lightweight mobile heat pump is under study for use in shelters on bare air bases. **DTO-MP.14: Force Protection Fortifications and Structures Technologies** will provide materials, criteria, and software suites for the design and construction of survivability measures to counter a wide variety of threats, including terrorism and advanced conventional munitions. **DTO-MP.15: Combined Fire Fighting and Hazardous Materials Ensembles** will permit sustained operations in intense heat and highly toxic chemical environments. An ultra-high-speed detection and suppression system will suppress munitions and high-energy-fuel fires at the incipient stage. **DTO-MP.16: Pavement Material, Design, and Repair System Criteria** will provide reliable pavements and airfields for advanced current and future-generation aircraft using "smart" and local materials at reduced construction and maintenance costs. Knowledge representation models, decision processes, and optional resource allocation techniques will ensure that installation-management decisions are integrated with force structure and weapon system decisions. Cold-climate construction techniques and inspection technologies will provide for expedient condition assessment and repair.

3.3.3.3 Basic Research Relevant basic research focuses on enhancing understanding of stress-strain relationships at the smallest aggregate of particles within the soil matrix, the constitutive behavior of construction materials, and soil moisture-strength relationships as a function of climatic influences on a global scale. These efforts directly contribute to development of a high-resolution, high-fidelity mobility model that accurately predicts worldwide vehicle movements, both on and off roads. In addition, research on constitutive behavior and micromodeling of asphalt concrete provides basic understanding of asphalt response to loads.

3.4 Environmental Quality

3.4.1 Warfighter Needs

Research and Development (R&D) in the Environmental Quality (EQ) subarea is undertaken in response to formal Service-approved user requirements promulgated through the Technology Requirements Strategy of 15 March 1995, that are intended to improve environmental performance, provide new capabilities, and reduce life-cycle environmental cost. This work contributes to the Joint Readiness Warfighter Objective and to all weapon and platform testing. DoD mission readiness requires unencumbered, low-cost operation of ships, aircraft, maintenance depots, shipyards, weapon stations, munitions plants, bases, and equipment. Environmental regulations at the local, national, and international levels restrict military operations and significantly increase operating costs. New technologies are developed for specific DoD problems when the best available technology is inadequate. Work is divided into four pillars. **Cleanup** -- Advanced technologies are under development to characterize and treat hazardous and toxic contaminants of military interest (e.g., explosives, energetics, dense nonaqueous phase liquids, and other organic materials) and reduce cleanup costs, expedite cleanup, and ensure the protection of human health and the environment. **Compliance** -- Work in this area provides for advanced "end-of-the-pipe" control, treatment, recycling, and disposal of hazardous, toxic, gaseous, liquid, or solid wastes from DoD systems, operations, and processes to meet existing and anticipated, air, water, land, and noise regulations. **Pollution Prevention** -- Processing methods are being improved to prevent the generation of contaminants and pollutants by DoD installations, facilities, and equipment. **Conservation** -- Work in this area is intended to mitigate and redress military operational impacts on earth, marine, and cultural resources at and around sea, land, and air operational ranges

3.4.2 Overview

3.4.2.1 Goals and Timeframes. Highlights of EQ goals and time frames are as follows: **Cleanup** -- By 2005, cleanup costs will be reduced by 50 percent. **Compliance** -- By 2002, the goals are to remove, concentrate, convert, or destroy contaminants and hazardous emissions to reduce waste disposal burdens; and to monitor and forecast noise and waste contaminant levels and behavior in order to control and predict pollutant and emission effects and reduce costs by 25-50 percent. By 2010, low-cost, high-performance technologies will be developed for new weapons and platforms and/or to meet increasingly stringent regulations.

Pollution Prevention -- The initial goal is to reduce by 50 percent the generation of toxic chemicals listed by the Environmental Protection Agency (EPA). After 2000, the goal is to continue to seek, in support of new defense systems, processes that are environmentally acceptable and at least maintain military performance. **Conservation** -- Work focuses on achieving sustainable mission support through understanding of the effects of high-impact military operations on the biophysical and cultural environment (e.g., the effects of smoke on plants and animals by 1999, the effects of maneuvers on threatened and endangered species [TES] by 2000).

3.4.2.2 Major Technical Challenges. **Cleanup** -- Challenges include finding ways to accommodate site heterogeneity (soil, water, and climate); the large number, varying concentrations, state of mixing, and unmapped contaminants encountered at cleanup sites; the inherent complexity of biological, chemical, and physical phenomena and technologies; the density and opaqueness of earth media; the interactions and pathways of aerobic and anaerobic biodegradation; and the different views of acceptable risk held by regulators and stakeholders. **Compliance** -- The challenges to be addressed included the diversity and complexity of waste streams, variability in the concentrations and composition of wastes, the energetic instability of some waste streams, and the destruction or conversion of wastes and contaminants without the production of unwanted or hazardous by-products. **Pollution Prevention** -- The challenge is to develop new materials and processes that not only are environmentally acceptable but also perform militarily as well or better than existing systems (e.g., materials that can replace chromium, nickel, and cadmium in DoD processes, and processes that prevent the generation of hazardous waste from ordnance manufacturing and military industrial operations). **Conservation** -- The challenges are to adapt military ranges to changes in mission, equipment, and training, and to understand and manage vastly complex ecosystems and their responses to stress. Affordable modeling and biophysical technologies must be developed to mitigate, restore, and minimize damage to natural and cultural resources while enabling unencumbered use of training and testing ranges.

3.4.2.3 Related Federal and Private Sector Efforts. Collaborative and cooperative R&D programs are conducted with EPA, the Department of Energy, the National Aeronautics and Space Administration, the U.S., Department of Agriculture, academia, and private industry. Relevant topics include in-situ and ex-situ bioremediation; DoD site characterization and analysis; DoD groundwater modeling; hot and cold plasmas; advanced membranes; specialized catalysts; regenerable chemical sorbents; electrochemistry; biotechnology; photolytic oxidation; sonic reaction enhancement; supercritical water oxidation; carrying-capacity models; natural resource characterization; and integrated decision support models for management of land, cultural resources, ecosystems, and TES. Existing technologies for pollution cleanup, control, and prevention (especially those used by the aerospace, electronics, and automotive industries) are employed fully before undertaking DoD S&T work.

3.4.3 S&T Investment Strategy

3.4.3.1 Technology Demonstrations. **Cleanup** -- The use of Peroxone will be transferred to demonstration/validation as an oxidation process for treating explosives-contaminated groundwater at half the cost of current carbon adsorption methods. Sensors and samplers for the penetrometer system used in site characterization and analysis will be demonstrated to show the potential to reduce costs by 50 percent as compared to current methods. Natural attenuation, which could reduce cleanup costs by up to 90

percent, will be demonstrated as a remediation alternative for hydrocarbon-contaminated sites. **Compliance** -- The use of plasma arc pyrolysis to destroy ships' solid waste will be demonstrated to verify a 98 percent reduction in waste mass while meeting environmental and shipboard operational constraints. Advanced membranes that concentrate ships' "graywater" will be demonstrated to show that 90 percent of the water can be discharged overboard safely. **Pollution Prevention** -- The Large Aircraft Robotic Paint Stripper, which employs high-pressure water, will be demonstrated to show 94 percent reductions in the generation of wastewater and methylene chloride, increased system availability to 95 percent, and reduction in person-hours by 50 percent. Nonpolluting fouling-resistant or fouling-release hull coatings, which exploit low-surface-energy and surface-oriented perfluorinated alkyl compounds, also will be demonstrated. **Conservation** -- Technology will be demonstrated that doubles the accuracy of predictions of subsonic noise in military operating areas and bombing ranges. A whale-monitoring system will be demonstrated that uses the Integrated Undersea Surveillance System to detect, classify, and count marine mammals. Technologies that model terrain and simulated soil erosion will be demonstrated to show their utility in reducing by 50 percent sediment in surface water from ranges and costs by 10 percent.

3.4.3.2 Technology Development. Technologies under development are listed below:

Technology	Purpose
Instrumentation, Sensors, & Monitors (Fiber Optics, Laser Fluorescence, Remote, Low-Level)	VOCs, DNAPLs, POLs, UXO, Water Quality, Treatment Process Control, Noise, Air Emissions, & Cultural & Natural Resources
Hazard Prediction & Assessment Modeling	Treatment Alts, Fate & Effects of Contaminants, & Ecosystem & Human Health Impacts
Biotechnology (Remed, Filtr, & Destr)	Mil Site Remed., PEP Wastes, HAPs, & VOCs
Advanced Waste Destruction Processes (Supercrit Fluids, UV/Chem Oxidation, etc.)	Solid, PEP, & Hazardous Wastes
Air Emissions Control (Nonthermal Plasma, Catalysts, Sorbents, Fuel Cells)	Jet Engine, Ground Equipment, & Ship Engine NO_x and Green House Gases
Waste Concentration/Separation (Membrane, Electrostatic, Ultrasonic, Radio Frequency)	Ship & PEP Waste Waters & Heavy Metal Sludges
Waste Immobilization and Vitrification	Treatment Residues and Lead-Based Paint
Nonpolluting Proc (CO_2, Oxygen Plasma, etc.)	Cleaning for Metal Working and Machining
Nonpolluting Coatings (e.g., Antifouling)	Ships, Aircraft, & Military Equipment
Acoustic Survey Techniques	Locate, Identify, & Track Marine Mammals

3.4.3.3 Basic Research. Basic research contributes to the improved understanding of the fundamental phenomena and underlying mechanisms needed to improve EQ technologies. This research helps enhance the effectiveness of contaminant sensing; contaminant biodegradation; advanced oxidation processes; modeling of geochemical and geophysical phenomena in contaminant transport; advanced biotechnology; plasma, sonolytic, and photolytic oxidation processes for Propellents Explosives and Pyrotechnics (PEP) waste; alternative materials and chemicals for pollution prevention; monitoring of land processes and TES; and gathering of scientific data for input into models for ecosystem management at land and sea ranges.

4.0 TECHNOLOGY AREA ROADMAPS AND RESOURCES

4.1 Technology Area Roadmaps

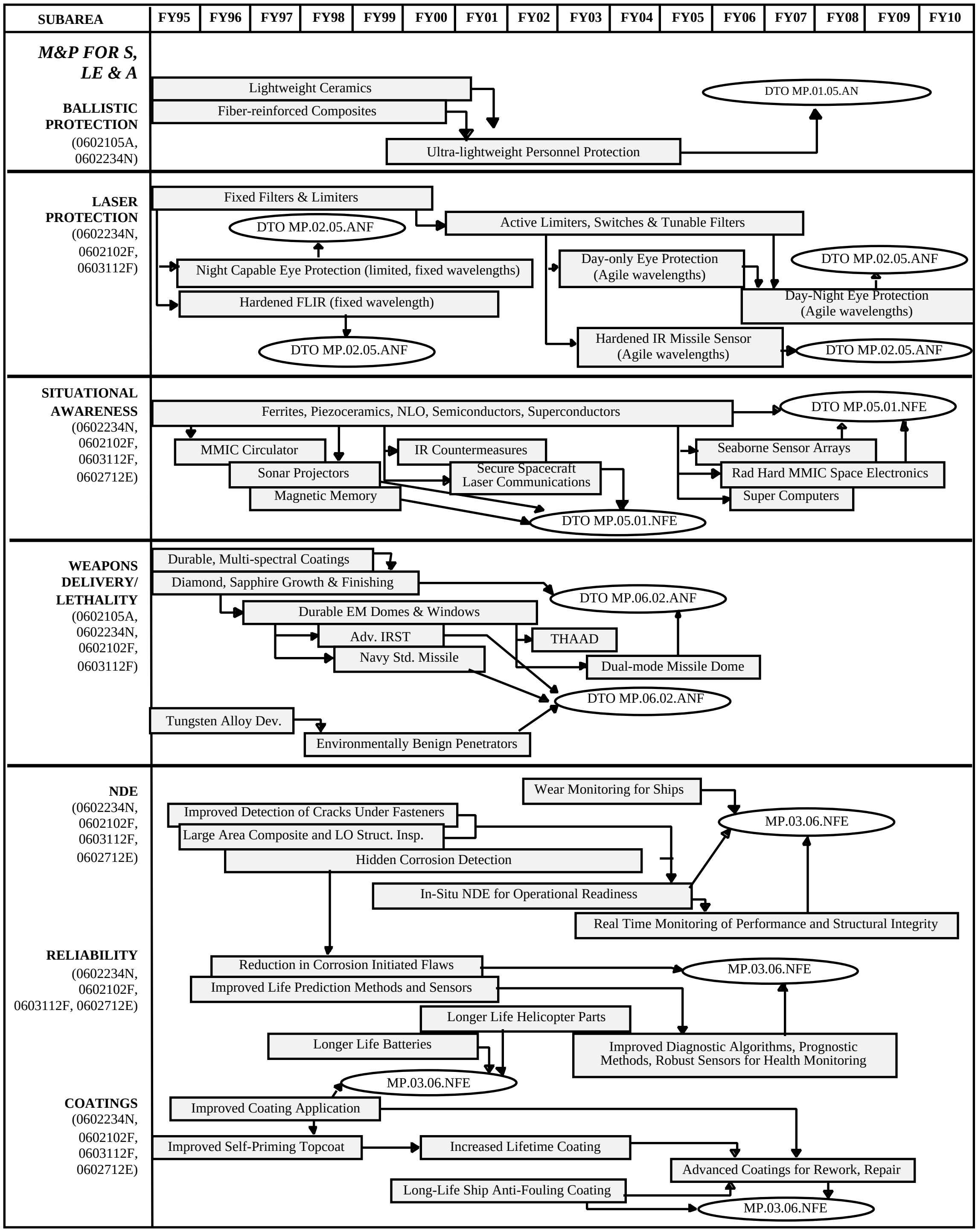


Figure V.1 Materials Technology Roadmap

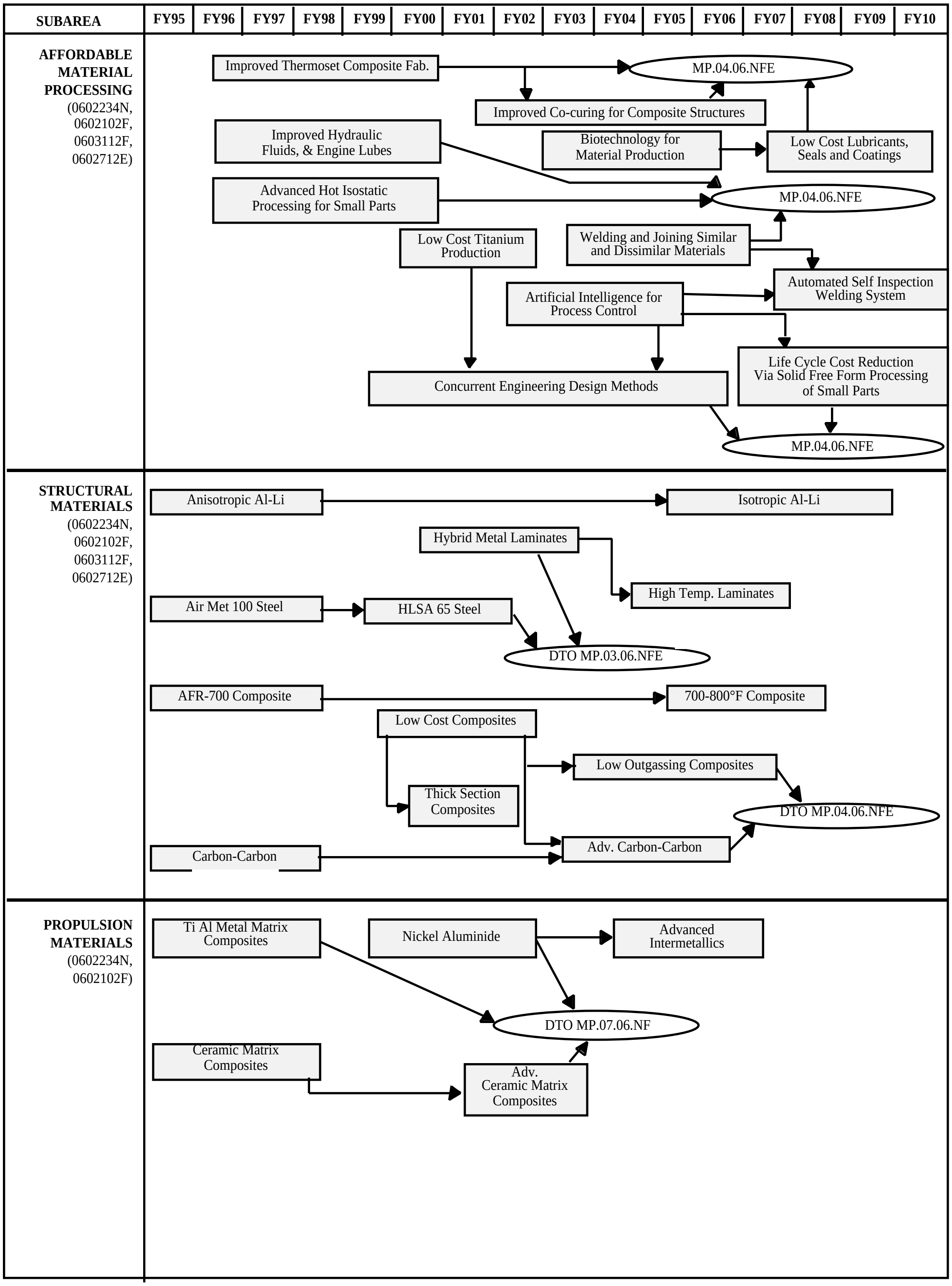


Figure V.1 Materials Technology Roadmap (concluded)

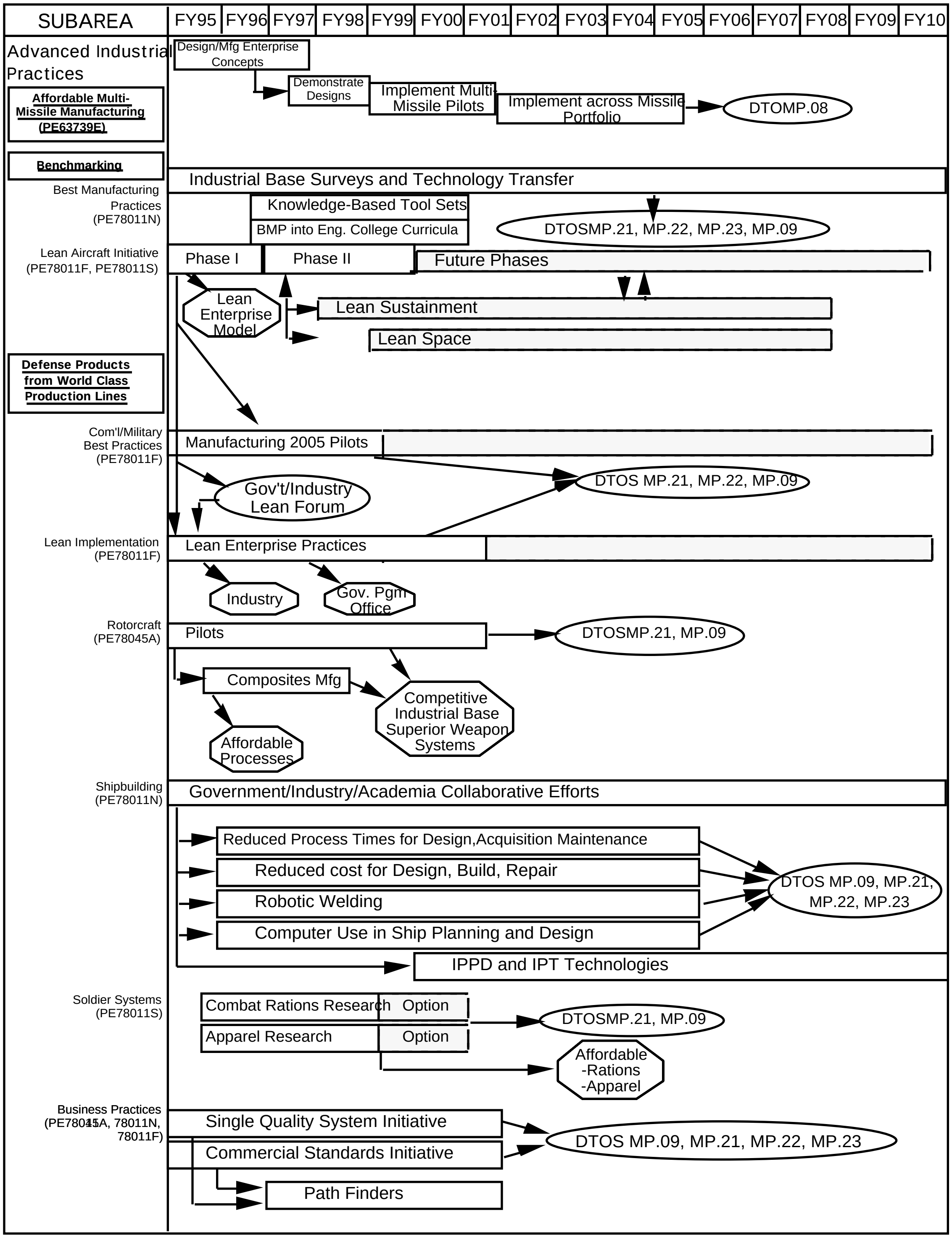


Figure V.2 Manufacturing Technology Roadmap

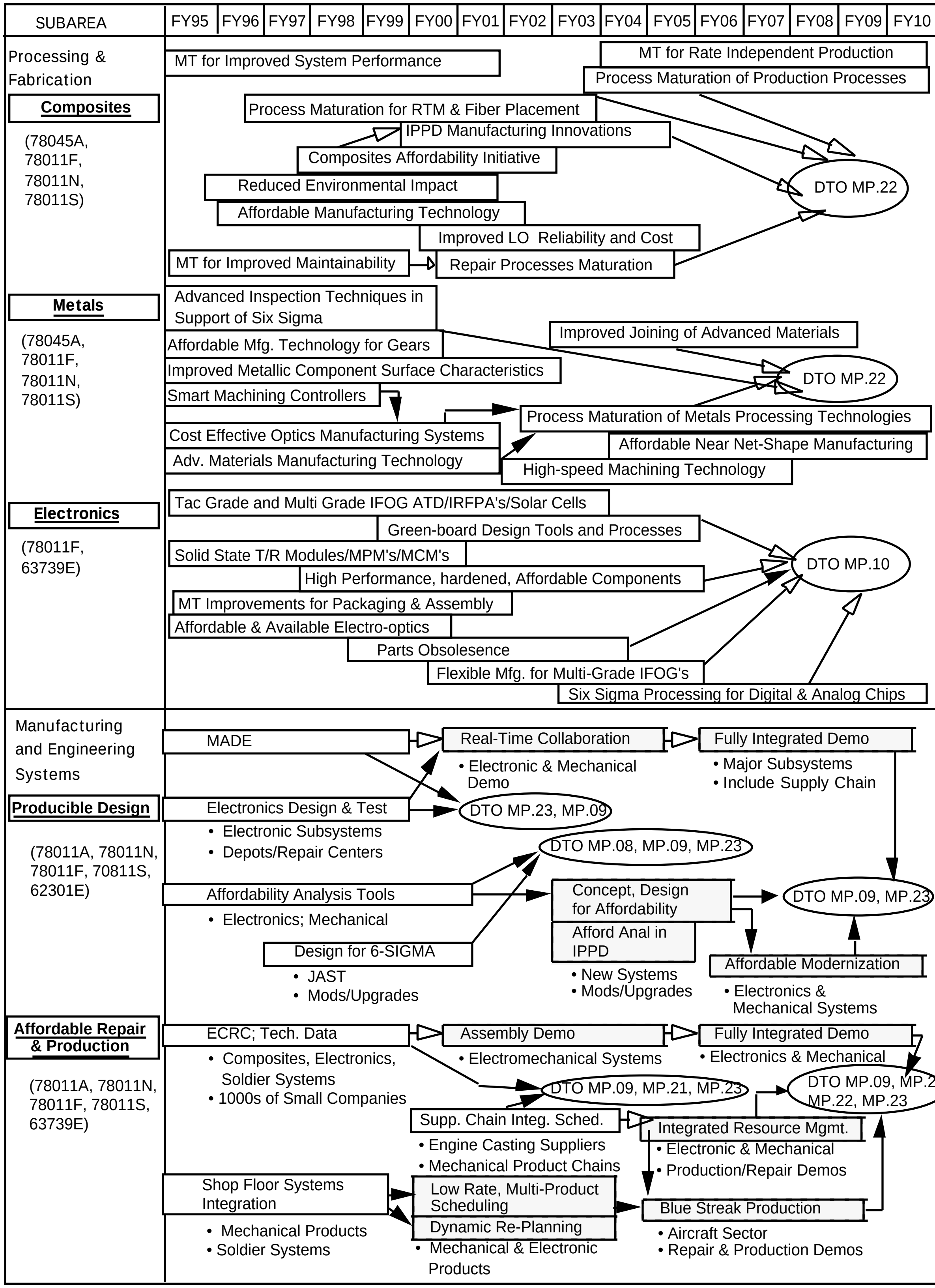


Figure V.2 Manufacturing Technology Roadmap (concluded)

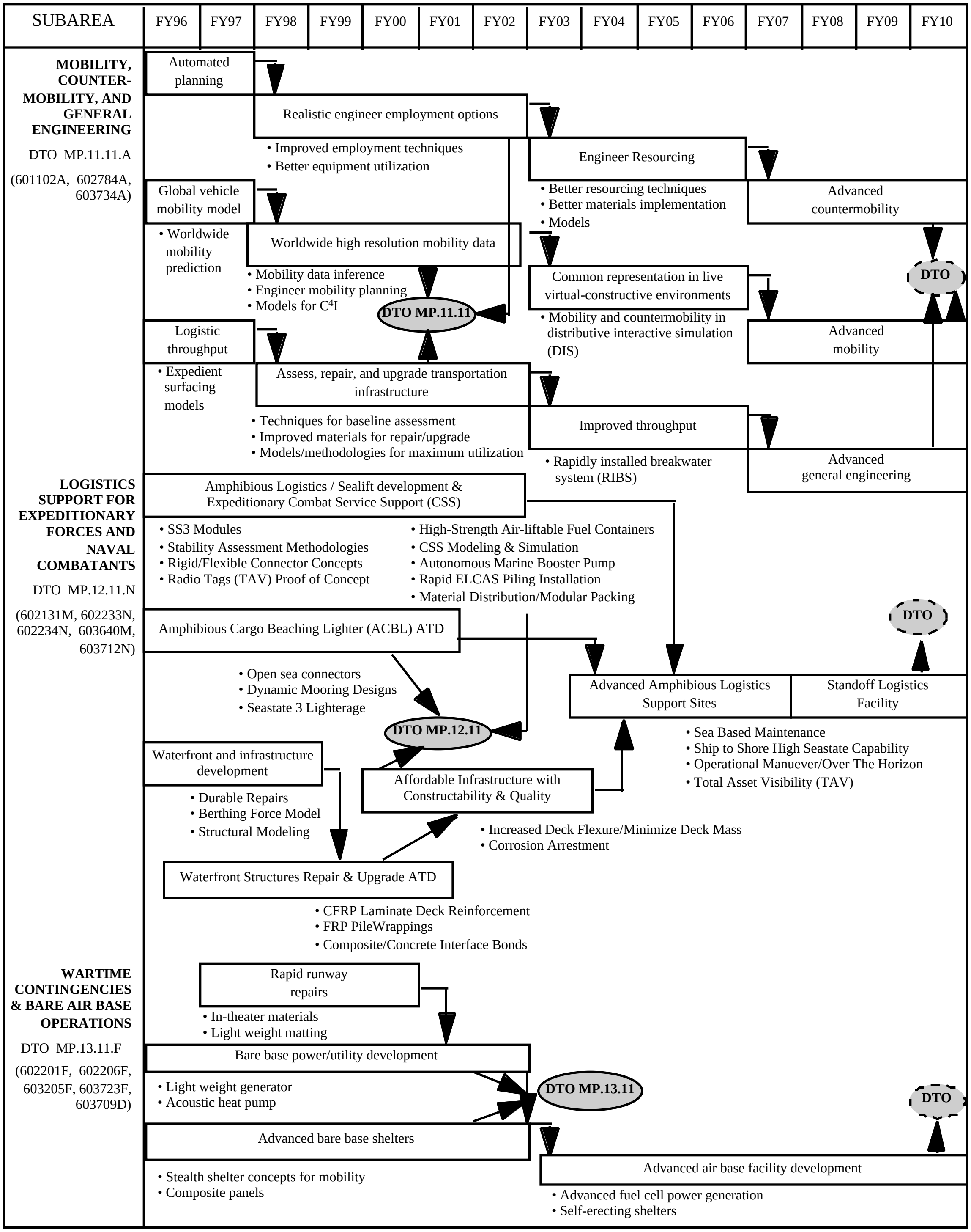


Figure V.3 Civil Engineering Technology Roadmap

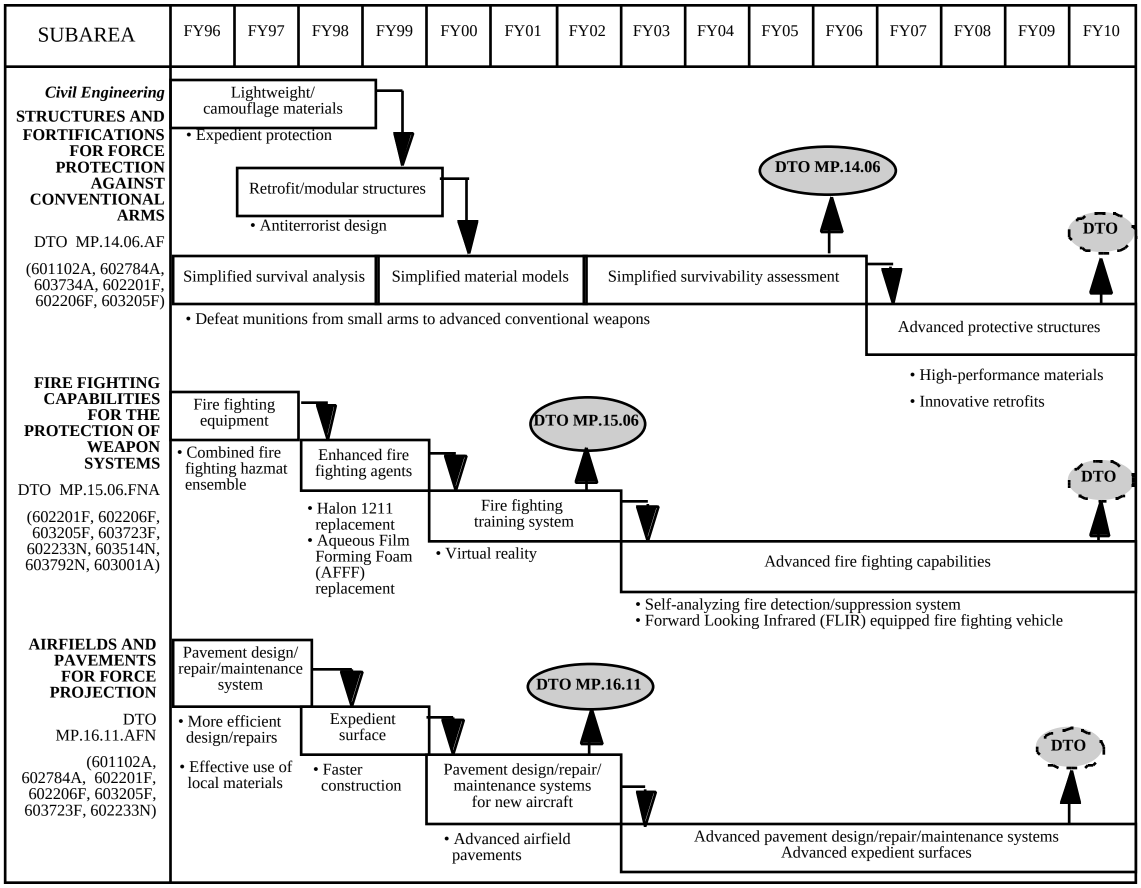


Figure V.3 Civil Engineering Technology Roadmap (concluded)

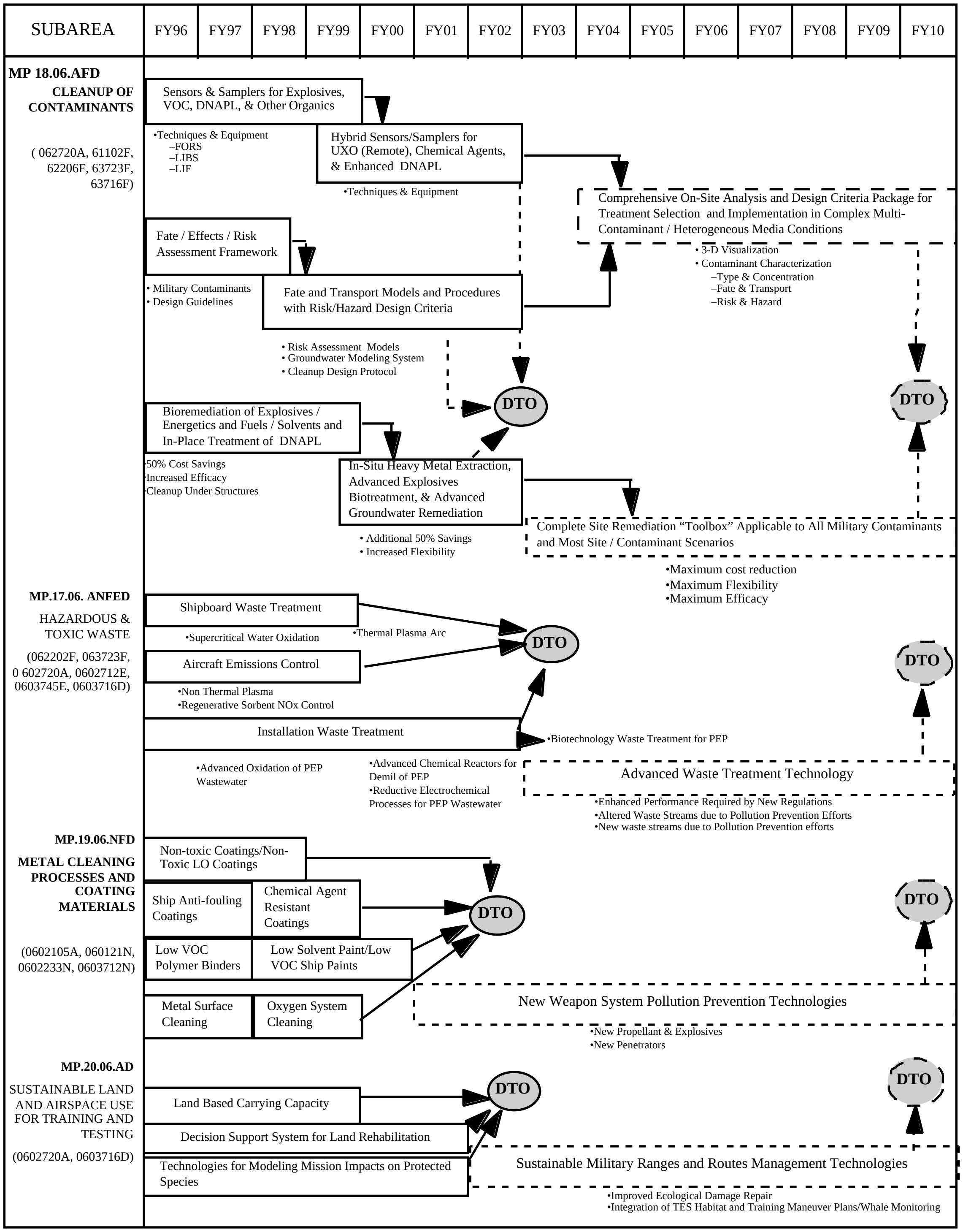


Figure V.4 Environmental Quality Roadmap

4.2 MATERIALS/PROCESSES TECHNOLOGY AREA RESOURCES ($M)

DTOs	Program Element	$ in millions FY96	FY97	FY98	FY99	FY00	FY01
MP.01.05.AN	0602105A	0.8	0.9	0.8	0.8	0	0
Protective Materials for	0602234N	0.6	0.6	0.6	0.8	0.8	0.8
Warfighters	DTO Total	1.4	1.5	1.4	1.6	0.8	0.8
MP.02.05.NF	0602234N	1.9	2.1	2.1	2.0	2.0	1.9
Laser Protective Materials	0602102F	4.2	3.2	3.3	3.5	3.6	3.9
	0603112F	10.6	10.2	10.2	10.6	11.0	11.4
	DTO Total	16.7	15.5	15.6	16.1	16.6	17.2
MP.03.06.NFE	0602234N	7.8	8.6	8.9	9.0	9.1	10.1
Materials to Prolong Life	0602102F	4.7	4.5	4.5	4.8	5.0	5.4
	0603112F	5.8	5.8	5.6	6.2	6.5	6.9
	0602712E	2.5	5.1	2.2	2.9	3.7	3.8
	DTO Total	20.8	19.4	21.2	22.9	24.3	26.2
MP.04.06.NFE	0602234N	6.3	6.9	7.2	7.2	7.5	7.5
Materials for Major Cost	0602102F	2.8	6.2	6.3	6.3	6.3	6.3
Reductions	0603112F	3.6	5.2	6.5	7.0	7.3	7.7
	0602712E	46.1	51.4	63.1	72.8	78.5	81.9
	DTO Total	58.8	69.7	83.1	93.3	99.6	103.4
MP.05.01.NFE	0602234N	2.2	2.4	2.5	2.7	2.8	3.0
Sensor and Device Materials	0602102F	6.5	6.5	6.7	7.1	7.4	8.1
	0603112F	1.5	1.5	1.5	1.5	1.5	1.5
	0602712E	2.5	3.3	2.2	2.9	3.7	3.7
	DTO Total	12.7	13.7	12.9	14.2	15.4	16.2
MP.06.02.ANF	062105A	0.2	0.2	0	0	0	0
Armament & Ordnance Materials	0602102F	0.4	0.4	0.4	0.4	0.4	0.4
	0602618A	0.2	0.2	0	0	0	0
	0602624A	0.8	1.0	0	0	0	0
	0603112F	1.8	1.9	0.5	0.5	0.5	0.5
	0602234N	0.8	0.8	0.8	0.9	0.9	0.1
	DTO Total	4.2	4.5	1.7	1.8	1.8	1.0
MP.07.06.NFE	0602234N	3.3	3.3	3.5	3.0	2.5	2.0
Materials for Propulsion	0602102F	11.4	11.2	11.3	12.3	12.9	13.9
	0602712E	10.5	12.7	20.7	19.0	15.3	16.0
	DTO Total	25.2	27.2	35.5	34.3	30.7	31.9
MP.08.06.E	0603734E	17.2	14.2	25.0	25.0	20.0	0
Affordable Multi-Missile							
Manufacturing (AM3) ATD							
	DTO Total	17.2	14.2	25.0	25.0	20.0	0
MP.09.06.ANFE	078045A	0.3	0.5	0.7	0.7	0.5	0.5
Producible Designs for Affordable	078011N	--	0.5	0.4	0.3	0.3	0.3
Force Modernization	078011F	2.2	2.9	4.6	4.5	4.5	5.6
	0602301E	11.1	14.7	16.0	15.2	13.0	14.8
	DTO Total	13.7	18.6	21.7	20.7	18.2	21.2
MP.10.06.FE	078011F	3.4	2.5	0	0	0	0
Interferome Fiber Optic Gyrotric	0603739E	19.5	21.9	8.4	0	0	0
(IFOG) Flexible Manufacturing							
	DTO Total	22.9	24.4	8.4	0	0	0

Figure V.5. Materials and Processes Technology Roadmap Resources
TOTALS MAY NOT AGREE DUE TO ROUNDING

DTOs	Program Element	$ in millions					
		FY96	FY97	FY98	FY99	FY00	FY01
MP.11.11.A	0602784A	4.3	3.2	2.2	2.3	2.3	2.3
Mobility, Countermobility, and General Engineering	0602784A	1.4	1.7	0.9	1.4	1.4	1.5
	DTO Total	5.7	4.9	3.1	3.7	3.7	3.8
MP.12.11.N	0602131M	3.0	2.9	3.0	3.1	3.2	3.2
Logistic Support for Expeditonary	0602233N	3.0	3.1	3.4	3.0	3.1	3.1
Forces and Naval Combatants	0602234N	0.4	0.5	0.5	0.5	0.6	0.6
	0603640M	0.6	1.9	2.5	2.8	3.1	3.1
	0603712N	2.2	3.1	2.0	2.0	0	0
	DTO Total	9.1	11.6	11.4	11.4	9.9	10.0
MP.13.11.FD	0602201F	0.8	0.9	1.2	0.9	1.1	1.1
Wartime Contingencies and Bare	0603205F	1.4	0.9	0.9	1.4	1.4	1.2
Air Base Operations	DTO Total	2.2	1.8	2.1	2.3	2.5	2.3
MP.14.06.AF	0602784A	0.8	1.0	4.0	4.2	3.9	4.0
Force Protection Against	0602201F	0.3	0.3	0.2	0.2	0.2	0.4
Conventional Arms	0603205F	0.5	0.4	0	0	0	0
	DTO Total	1.7	1.7	4.2	4.4	4.1	4.4
MP.15.06.FN	0602201F	0.7	0.5	0.6	1.1	0.8	0.8
Fire Fighting Capabilities for the	0603205F	0.7	1.0	0.7	0.7	0.8	0.9
Protection of Weapon Systems	0602233N	1.0	1.1	0	0	0	0
	0603514N	0.7	0.4	0.8	1.3	1.8	1.6
	0603792N	0.8	0.9	0.1	3.1	0	0
	DTO Total	3.4	3.9	2.2	2.8	3.4	3.3
MP.16.11.AFN	0602784A	--	--	1.9	2.0	1.6	1.7
Airfields and Pavements for	0602201F	0.3	0.5	0.3	0.2	0.3	0.3
Force Projection	0603205F	0.2	0.2	0.5	0.4	0.6	0.6
	0602233N	0.2	0	0	0	0	0
	DTO Total	0.7	0.7	2.7	2.6	2.5	2.6
MP.17.06.ANFED	0602720A	0.7	0.3	0.8	1.1	1.0	0.7
Hazardous and Toxic Waste	0602720A	0.3	0.4	0.3	0	0	0
	0602233N	0.4	0	0	0	0	0
	0603792N	--	3.0	6.0	5.0	0	0
	0602202F	5.8	5.8	6.1	9.2	12.1	13.2
	0603723F	4.4	3.9	3.6	5.3	6.4	7.7
	0605502F	2.0	2.0	2.0	2.0	2.0	2.0
	0603716D	1.2	1.8	0.9	1.1	0.3	0.3
	DTO Total	14.9	12.1	19.7	23.7	20.8	23.2
MP.18.06.AFD	0602720A	1.7	2.3	2.6	3.9	4.1	4.3
Cleanup of contaminants	0602202F	3.3	4.2	4.5	3.9	4.0	3.4
	0603723F	3.4	3.0	3.7	2.7	2.4	2.3
	0605502F	2.0	2.0	0	0	0	0
	0603716D	10.5	11.3	11.9	10.2	0	0
	DTO Total	20.9	22.8	22.7	20.7	10.5	10.0
MP.19.06.NFD	0603712N	4.1	1.8	1.6	1.5	1.0	0.8
Metal Cleaning Processes	0602234N	0.5	0	0	0	0	0
and Coating Materials	0603716D	2.0	2.3	0.3	0	0	0
	0708054F	--	0.5	0.3	0	0	0
	DTO Total	6.5	4.6	2.2	1.5	1.0	0.8

Figure V.5. Materials and Processes Technology Roadmap Resources (cont.)
TOTALS MAY NOT AGREE DUE TO ROUNDING

DTOs	Program Element	$ in millions					
		FY96	FY97	FY98	FY99	FY00	FY01
MP.20.06.AD	0602720A	1.1	0.8	2.7	3.6	3.1	3.3
Sustainable Land and Air-Space	0603716D	1.5	2.5	2.5	3.0	1.0	0
Use for Training and Testing	DTO Total	2.6	3.3	5.2	6.6	4.1	3.3
MP.21.06.ANFS	078045A	0.9	0.7	0.2	0.2	0.4	0.6
Affordable Industrial Processes	078011N	2.2	5.6	3.8	3.5	3.5	3.6
and Practices	078011F	19.9	25.4	14.0	13.2	13.3	16.9
	078011S	2.0	2.0	2.0	2.0	2.0	2.0
	DTO Total	25.0	33.7	20.0	18.9	19.2	23.1
MP.22.06.ANFS	078045A	27.1	15.7	16.7	16.7	17.4	18.0
Capable Manufacturing	078011N	48.2	41.1	28.5	24.6	25.3	26.4
Processes	078011F	22.2	15.7	31.3	34.0	36.7	32.4
	078011S	2.0	2.0	2.0	3.0	2.0	2.0
	0603739E	17.1	4.0	0	0	0	0
	0602712E	1.1	0.9	1.0	1.3	1.7	1.8
	0603746E	47.7	37.4	50.0	0	0	0
	DTO Total	165.4	116.8	129.5	79.6	83.1	80.6
MP.23.06.ANFES	078045A	0.3	0.4	0.2	0.3	0.5	0.5
Affordable Short-Lead-Time	078011N	0.5	0.5	0.4	0.3	0.3	0.3
Repair and Production	078011F	13.2	5.6	3.4	1.3	2.0	4.1
	078011S	3.0	3.0	3.0	3.0	3.0	3.0
	0603739E	33.0	20.7	15.0	0	0	0
	DTO Total	49.9	30.2	22.0	4.9	5.8	7.9

Figure V.5. Materials and Processes Technology Roadmap Resources (concluded)
TOTALS MAY NOT AGREE DUE TO ROUNDING

MATERIALS AND PROCESSES
ACRONYMS

AM^3	Affordable Multi-Missile Manufacturing
AMRAA	Advanced Medium Range Air to Air Missile
ATD	Advanced Technology Demonstrator
AWACS	Airborne Warning and Control System
CMC	Ceramic Matrix Composite
DOC	Department of Commerce
DOE	Department of Energy
DTO	Defense Technology Objective
EFOG-M	Enhanced Fiber Optic Guided Missile
EPA	Environmental Protection Agency
EQ	Environmental Quality
FAA	Federal Aviation Administration
G-ENG	General Engineering
GEOSAT	Geosynchronous Satellite
HSLA	High Strength Low Alloy
HY	High Yield
IFOG	Interferometric Fiber Optic
IPPD	Integrated Product/Process Development
IR	Infra Red
IRST	Infra red Search Track
JSTARS	Joint Surveillance Target Attack Radar System
JSOW	Joint Stand Off Weapon
LAV	Light Amphibious Vehicle
LOSAT	Line of Sight Anti Tank
ManTech	Manufacturing Technology
MERWS	Modular Erectable Rigid Wall Shelter
M/CM	Mobility/Countermobility
MMC	Metal Matrix Composite
NASA	National Aeronautics and Space Administration
NDE	NonDestructive Evaluation
NDI	NonDestructive Inspection
NSSN	New Attack Nuclear Submarine
OMC	Organic Matrix Composites
EPA	Environmental Quality
O&S	Operation and Support
PEP	Propellants,
POL	Petroleum, Oil, Lubricants
R&D	Research and Development
TD	Technology Demonstration
TES	Threatened and Endangered Species
Ti	Titanium
TO	Theater of Operation
TWT	Traveling Wave Tube
UAV	Unmanned Aerial Vehicle
UXO	Unexploded Ordnance
VLSI	Very Large Scale Integrated

VI. FY 1997 DEFENSE TECHNOLOGY AREA PLAN FOR BIOMEDICAL SCIENCE AND TECHNOLOGY

1. INTRODUCTION

1.1 Definition/Scope

The Defense biomedical science and technology program is aligned into seven technology subareas (Figure VI.1.), with joint coordination and cooperation within and among subareas accomplished through the Armed Services Biomedical Research Evaluation and Management (ASBREM) Committee and its subordinate Joint Technology Coordinating Groups. The program is focused to yield superior technology in support of the DoD mission to provide health support and services to U.S. Armed Forces. Unlike other national and international medical S&T investment which is focused upon public health problems of the general population, military medical S&T is concerned with preserving combatants' health and optimal mission capabilities despite extraordinary battle and non-battle threats to their well-being. Preservation of individual health and well-being sustains warfighting capabilities. See Resource Appendix for funding of this Defense Technology Area.

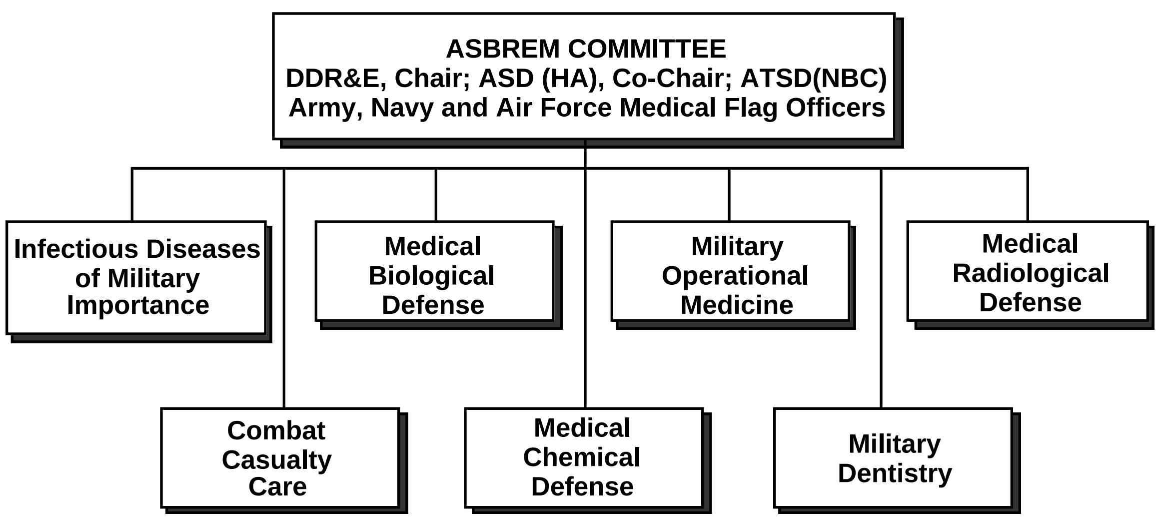


Figure VI.1. Planning Structure

1.2 Strategic Goals

- Provide medical technology to enable a full spectrum of military operations for crisis and conflict resolution
- Protect and sustain warfighters from battle and non-battle health threats
- Optimize military performance; survival and stabilization of combat casualties
- Provide the world's best casualty evacuation and medical support
- Provide new-generation medical equipment to support battle and non-battle operations

1.3 Acquisition/Warfighting Needs

Modern warfighting strategy emphasizes preparedness for regional rather than global conflict utilizing continental U.S. (CONUS)-based forces. Joint Staff defined requirements emphasize preventive medicine to reduce casualties resulting from disease and non-battle injuries, immediate life-saving treatment, resuscitative care and stabilization, and technologies for rapid evacuation of casualties to definitive care CONUS-based fixed facilities. The deployable health service support structure must reduce its in-theater medical footprint and the lift requirements associated with a forward positioning of medical care assets. Capability to enhance personnel readiness for joint and combined operations is an identified warfighting need.

Figure VI.2. shows the technology forecast for the military BS&T area. Development of novel vaccines will protect deployed forces against a number of parasitic and life-threatening infectious diseases to which they are now vulnerable. Life support systems with enhanced mobility and physiological monitoring capability will be provided to enable in-flight maintenance of patient stabilization, allowing safe long-range evacuation of critically injured service personnel. Provision of vaccines, protectants, and therapeutics directed against biological and chemical threat agents will deter and constrain proliferation of these weapons while defeating their use. Scientifically based operational doctrine and ration supplements will improve and better sustain individual operational capabilities. Evacuations for dental emergencies will be reduced by application of improved, forward diagnostic and dental treatment technologies. New radioprotective strategies will be developed that provide protection against both the prompt and late (cancer) effects of ionizing radiation.

Subarea	Baseline	2000	2005	2010
Infectious Diseases of Military Importance	Malaria treatment drugs Vaccines for hanta virus Monoclonal antibodies for forward diagnosis	Campylobacter vaccine Field assays for malaria diagnosis Topical antileishmanial	Combined malaria vaccines (falciparum/vivax) Combined dengue vaccines	Broad spectrum antivirals Single dose vaccines Shigella DNA vaccine
Combat Casualty Care	Antimicrobial dermal dressing Intraosseous vascular access device Small volume resuscitation solutions 10-12 wk extended liquid red cells Frozen platelets in DM50	Improve blood storage Reduce far-forward IV fluid requirements Medical decision-assist devices Provide individual O2 generators for evacuation	Free-radical scavenger to reduce secondary effects of trauma Intensive care evacuation platform Local hemostatic agents Field blood substitute	Universal donor reagents "Extensive care" evaluation platform Hibernation drug O2 free-radical scavengers
Medical Biological Defense	Microencapsulated vaccines for SEB Genetically engineered vaccines for VEE	Bioengineered toxin scavengers Ricin protection	Nucleic acid therapy Human monoclonal antibody therapy	Nucleic acid immunizations Combined oral vaccine
Medical Chemical Defense	Cyanide pretreatment drug Topical skin protectant	Catalytic pretreatment for agents Reactive topical skin protectant	Monoclonal antibodies for nerve agent protection Vesicant agent countermeasure	Receptor-targeted therapeutics Immunoprophylaxis for CW agents Vesicants countermeasure
Military Operational Medicine	Blast standards Spatial disorientation model Vestibular test battery Visual performance with flat panel displays	Performance enhancing nutrients Vigilance/alertness monitor Electromagnetic radiation standards RFR dosimeter Advanced laser protection	Physiological status monitors Spatial awareness incorporation into trainers Improved injury prevention guidelines Pharmaco- dynamic model of neurotoxicity	Sleep/alertness enhancers Treatments for laser retinal injury Memory enhancers Strength enhancers
Military Dentistry	Microencapsulated antibiotics Filmless dental imager Rapid dental diagnostics	Ultralong duration anesthetics Fiberoptic dental probe	Non-metal shrapnel visualization CAD/CAM prosthetics	Surgical robotics Dental disease prophylaxes Epidemiology update
Medical Radiological Defense	Immunomodulator therapy Anti-emetic compounds	Novel radioprotective drugs Fieldable biodosimetry capability	Modeling for casualties in NBC environments	Combined injury treatment protocols

Figure VI.2. Technology Forecast

2. DEFENSE TECHNOLOGY OBJECTIVES (DTOs)

Subarea	Number	DTO Title
Infectious Diseases of Military Importance	MD02J00A MD06J00A MD12J00A	Vaccines for Prevention of Malaria Prevention of Diarrheal Disease Antiparasitic Drugs Program
Combat Casualty Care	MD03J00AN MD11J00AN	Blood Loss, Blood Products & Fluid Resuscitation Management & Treatment of Trauma & Sequelae
Medical Biological Defense	L.07	Medical Biological Defense
Medical Chemical Defense	L.02	Medical Chemical Defense
Military Operational Medicine	MD01J00ANF MD08J00ANF MD09J00ANE MD10J00ANF MD13J00ANF	SUSOPS Enhancement Ensemble Laser Bioeffects Countermeasures Adv. Medical Technology (Field Medical Support)* Toxic Hazards Evaluation Tools RF Radiation Bioeffects Countermeasures

* Joint subarea program with Combat Casualty Care

Figure VI.3. Defense Technology Objectives

3. TECHNOLOGY DESCRIPTION

3.1 Infectious Diseases Of Military Importance

3.1.1 Warfighter Needs

Infectious diseases pose a significant threat to successful completion of military missions, especially when U.S. forces have no natural immunity or protection. As examples: diarrheal disease affects 20-30% of soldiers deployed outside continental U.S. (OCONUS); malaria infection rates of up to 600 per 1,000 troops annually were seen in Vietnam; and cutaneous and visceral leishmaniasis infections were the most common chronic infection in Operation Desert Shield/Storm (ODS/S) veterans. Prevention of disease by immunization is a valuable force multiplier and enables the full spectrum of military alternatives for resolution of regional conflict. The Joint Staff has requested priority for medical technology supporting prevention and treatment of diseases. Near-term control measures will depend on existing personal protective measures and personal hygiene for the prevention of malaria and diarrheal diseases. Mid-term impact includes adding a licensed antibiotic to the routine treatment of drug resistant malaria. Far-term introduction of new vaccines will prevent the most common causes of malaria and bacterial diarrhea experienced by U.S. military personnel and provide new drugs for treating parasitic diseases like leishmaniasis.

3.1.2 Subarea Overview

3.1.2.1 Goals and Timeframes. The goals of the Infectious Disease subarea are to protect soldiers from incapacitating infectious diseases by the development of vaccines and pretreatment drugs and to return infected soldiers to duty by the discovery of effective drug treatment. The most common worldwide infections affecting U.S. warfighters can be controlled by vaccines by the year 2007. In addition, this program will identify endemic disease threats throughout the world so that informed decisions can be made about military operations in these areas.

Vaccines are the most cost-effective means of preventing illness. Since it commonly requires 20 years or more to develop and field an FDA-approved vaccine, research on infectious diseases is an ongoing, simultaneous application of new technology to the control of many different militarily important infectious diseases. Infectious disease organisms such as hantavirus, HIV, and those causing malaria are continually evolving and appearing in new locations. Benign diseases today can become militarily important tomorrow. Military infectious disease research must remain at the forefront of technological advances to address these problems before they become warstoppers.

3.1.2.2 Major Technical Challenges. Major technical challenges include identification of effective vaccine approaches that address all aspects of infectious processes (e.g., multiple developmental stages of parasites during their life cycle, multiple virulence factors involved in bacterial infections); overcoming development of parasite resistance to antimalarial drugs and insecticides; lack of appropriate animal models for many diseases (necessitating human studies, when feasible), risk assessment of new diseases; and simplified methodology for disease diagnoses.

3.1.2.3 Related Federal and Private Sector Efforts. Only the military investigates infectious diseases from basic research through concept exploration to product

development and has a combination of CONUS and OCONUS laboratories to allow all stages of product development and evaluation. Military research is advanced by over 190 Cooperative Research and Development Agreements (CRDAs) and Material Transfer Agreements with industrial and academic partners. The National Institutes of Health (NIH) focus on basic research and vaccine prototypes, but lack U.S. Government facilities for testing products for endemic disease outside the U.S. The Centers for Disease Control and Prevention (CDC) are experts at epidemiology and vaccine delivery, but lack the capability for vaccine preparation and testing in OCONUS locations. Academic centers focus on basic research and pathogenesis. Industry emphasizes products marketable in the U.S., and limits basic research. The military program is coordinated with other Federal programs to prevent unnecessary duplication of efforts; these and private sector efforts are exploited to the greatest extent possible. An initiative for interagency cooperation in global surveillance for emerging disease using advanced technology will enhance communication links between OCONUS and CONUS labs, the NIH and the CDC.

3.1.3 S&T Investment Strategy

Technology efforts are arrayed according to the type of etiologic agents that cause infection and disease. Distribution of investment within and among these broad agent areas is allocated in accordance with the impact of each agent on operations, the potential contribution of technology to overcoming the threat posed by the agent, and the feasibility of achieving technology objectives through military investment. As infectious disease research progresses, new technologies for improving diagnosis, treatment, and prevention are broadly shared among different research efforts.

3.1.3.1 Technology Demonstrations. The Antiparasitic Drug Program includes the validation of the effectiveness of candidate drugs prior to full scale development. FDA regulations, as promulgated through the Code of Federal Regulations (21 CFR), restrict demonstrations involving unlicensed drugs to laboratory testing in nonhuman models. Before starting human testing, an Investigational New Drug Application must be filed with the FDA. Drugs currently under investigation include one licensed antibiotic for which malaria is an unlicensed indication for use, and four other antimalarial drug candidates. A new drug for the treatment of leishmania skin lesions is also under study. Research will explain mechanisms of parasite resistance to drugs and find alternative countermeasures to resistance in the far-term.

3.1.3.2 Technology Development. Medical countermeasure development efforts are arrayed into the following functional areas:

- Parasitic Diseases, including vaccines for prevention of malaria, development of antiparasitic drugs, identification of antiparasitic drug resistance patterns, identification and control of insect vectors for parasitic diseases, diagnosis of leishmaniasis, and vaccines for prevention of leishmaniasis.

- Bacterial Diseases, including vaccines for Shigella, enterotoxigenic *E. coli*, Campylobacter, meningococci, and gonococci, and organisms responsible for sepsis and septic shock; as well as development of improved vaccine production and delivery methods and epidemiological studies of emerging infectious diseases of military importance.

- Viral Diseases, including vaccines or treatments for dengue virus, hepatitis virus, viral hemorrhagic fever and encephalitis, and forward deployable diagnostic tests.
- Rickettsial Diseases, emphasizing assessment of emerging patterns of drug resistance.

3.1.3.3 Basic Research. For every infection, basic research must focus on characterization of the etiologic agent, transmission of the agent, pathogenesis and natural history of disease, the protective host immune response, and finding suitable *in vitro* and *in vivo* models of infection. Military infectious disease basic research funding is focused to exploit advances resulting from other Federal and private sector investments for use in DoD applications, and also to provide new medical knowledge. These programs are managed to ensure provision of strong scientific capabilities to effectively exploit fundamental advances in biomedical science in a manner that is responsive to the peculiar and unique research needs of the technology area.

3.2 Combat Casualty Care

3.2.1 Warfighter Needs

Combat casualty care is constrained by logistics, manpower, and the operational environment; constraints which pose unique challenges that are unknown in civilian trauma care. Military casualties may wait for hours before definitive medical care can be provided, and initial treatment and subsequent evacuation occurs in austere field, airborne, and shipboard environments characterized by limited supplies (e.g., blood, resuscitation fluids) and limited diagnostic and life-support equipment. Fifty percent of combat deaths are due to uncontrolled blood loss, and provision of perishable blood and blood products far forward presents severe logistic challenges. Head injury and complications from trauma are also major contributors to loss of life and extended morbidity. Provision of acute and critical care is labor intensive, and must frequently be provided by non-physician medical personnel. Military medical personnel must be provided with the tools and techniques to overcome these austere conditions. New doctrine emphasizes immediate life-saving treatment, resuscitative care and stabilization, and evacuation of casualties to definitive care at CONUS-based fixed facilities, with few lengthy in-theater hospital stays. The Joint Staff has requested research and development (R&D) emphasis on immediate life-saving treatment, resuscitative care and stabilization of medical casualties, rapid casualty evacuation with maintenance of medical support, and smaller, lighter medical equipment sets to reduce requirements for strategic and tactical lift for deployment and sustainment. Products and knowledge generated through combat casualty care research will result in smaller, lighter equipment, with enhanced capability to supplement and complement the skills of far-forward medical personnel. This will field state-of-the-art trauma care on the front lines of combat where it is needed most. This research will also improve the supply of critical blood and blood products and reduce large manpower and logistics burdens associated with processing, storing, and maintaining fresh supplies of these perishable items at forward echelons. Efforts will also enhance the operational capability of military medical personnel in combat environments, resulting in conservation of medical manpower, reduced reliance on field hospitals, and reduced acute and long-term military health care costs. These efforts,

along with development of new modalities to treat intractable medical problems of particular significance in military casualty populations will reduce combat deaths and disability, enable far-forward and sustained quality of care through all levels.

Near-term opportunities include the demonstration of modules for field collection and storage of medical data, which ultimately will impact operational capabilities by enhancing medical situational awareness, improving in-theater patient regulating, improving continuity of care through all levels, and enabling more accurate diagnosis in rear areas. Mid-term opportunities for transition to advanced development include enhanced storage modalities of liquid blood and blood products to reduce logistics burdens for sustainment of medical units, and the demonstration of advanced, intensive-care life-support evacuation platforms to enable efficient long-range air evacuation with sustained medical support. Long-term transition opportunities include countermeasures to mitigate brain and spinal cord trauma, improving survival, reducing long-term disability, and maintaining physical performance capability.

3.2.2. Subarea Overview

3.2.2.1 Goals and Timeframes. A near-term goal is to enhance diagnostic and triage methods and information processing for the rapid determination of various trauma-specific medical indices; this will aid in triage processes and advanced medical management. A second near-term goal is to reduce the present logistic burden. Efforts that will both minimize the weight and cube of those medical materials which are required to be far-forward, and which reduce the number of items projected as necessary are required to better enable U.S. forces to fight and win. A mid-long-term goal is to improve battlefield treatment capabilities at Echelons 1 and 2 to reduce mortality and morbidity. Also in the mid-long term, medical management of disease and non-battle injuries will be improved to minimize lost duty time. A long-term goal is to fully exploit advanced sensors and intelligent systems to extend advanced casualty diagnostics and treatment far-forward.

3.2.2.2 Major Technical Challenges. Major technical challenges include: identification of effective, nontoxic oxygen-carrying blood substitutes; identification of early prognostic physiological indicators of shock, and the development of corresponding noninvasive or minimally invasive sensing technologies; stabilization of red blood cells without destroying function while eliminating in-theater pre-transfusion processing requirements; overcoming immune system responses to donor blood cells; lack of knowledge regarding the physiologic and cellular factors underlying the body's response to hemorrhage and subsequent resuscitation; reversing complex detrimental inflammatory and physiological cascades initiated by reduced blood flow and anoxia subsequent to hemorrhage; and lack of knowledge of the detailed mechanisms responsible for brain edema and cytotoxicity following head injury.

3.2.2.3 Related Federal and Private Sector Efforts. The NIH are the major sponsor of U.S. biomedical scientific research on trauma, providing estimated annual funding of approximately $120 million. The NIH provide basic research in injury mechanisms that is exploited by military researchers. However, much of the NIH program is directed at within-hospital management of problems such as septic shock, blunt trauma, and wound healing, while the military focuses on prehospital resuscitation and life support. Industry, by and large, is uninterested in prehospital trauma care

research because of the difficulty and high cost of the required clinical research in relation to the relatively small anticipated market for products. The military actively solicits and exploits private sector expertise through extramural contracts with universities and industry, and via more than 20 CRDAs between civilian firms and the government in support of combat casualty care research projects.

3.2.3 S&T Investment Strategy

Technology efforts are arrayed against functional threat areas that impact on the quality and efficiency of early phases of trauma care: prehospital care (identification, diagnosis, triage, resuscitation, stabilization, and life support, including care during extraction from combat and evacuation), resuscitative and life-saving surgery, and critical care. S&T thrust areas are necessarily diverse to address the diversity of technologies required within these areas, encompassing medical knowledge, drugs, biologicals, and medical devices. Investment within and among threat areas is allocated in accordance with each threat's impact on combatants' health and frequency of injury occurrence, or its impact on medical operations (including logistics and manpower considerations); the potential contribution of technology to overcoming each threat; and the feasibility of achieving technology objectives through military investment.

3.2.3.1 Technology Demonstrations. The Advanced Medical Technology (Field Medical Support) effort will provide advanced noninvasive physiological sensors for life-support monitoring and diagnosis; lightweight, portable fluid and ventilatory support equipment; and intelligent medical decision-making systems, to provide early state-of-the-art life support and care during evacuation that is sustainable with minimal manpower. Individual components of the system will be developed in stages, focusing initially on manually operated platforms and progressing ultimately to a computer-assisted life-support system integrated with telemedicine systems under development in other programs. Efforts will exploit advances in basic knowledge of the pathophysiology of shock, and will focus on the integration of noninvasive sensor, microelectronic, and information-processing technologies into novel systems. The physiological sensing technology that will be developed as part of these systems can, in addition to its uses in trauma care, provide real-time awareness of operational capability for functioning personnel; thus, this demonstration is being jointly supported by both the Military Operational Medicine and the Combat Casualty Care subareas.

3.2.3.2 Technology Development. Efforts are arrayed into the following functional areas:

- Combat Casualty Assessment, including far forward medical data collection and management systems.
- Blood and Resuscitative Fluids, including preservation of and substitutes for blood and blood products, minimizing traumatic blood loss, and materials and doctrine development for fluid resuscitation.
- Combat Trauma, including discovery and development of drugs, biologicals and medical procedures to prevent or minimize secondary organ system injury and failure (including brain and spinal cord injury) after major trauma; repair of musculoskeletal injuries; countermeasures to systemic sepsis; care of combat casualties in extreme environments; and the development of

diagnostic and therapeutic medical devices and associated software and data processing systems for resuscitation, stabilization, life support, and surgical support.

3.2.3.3 Basic Research. Basic research focuses on physiological, humoral and cellular responses to hypoxic, ischemic, anoxic, and other types of injury, in order to identify potential diagnostic and prognostic indicators and sites for medical intervention, and on finding suitable *in vitro* and *in vivo* models of injury.

3.3 Medical Biological Defense

3.3.1 Warfighter Needs

A biological warfare (BW) attack could produce thousands of casualties over an area of thousands of square kilometers. Utilization of vaccines and pretreatments to prevent casualties can protect the fighting force and maintain unit operational effectiveness against this contingency. In the absence of complete prophylaxis, diagnostic capabilities can enhance treatment, reduce mortality and improve return to duty. The direct payoff for biological defense research is the reduction, even elimination, of casualties which would otherwise follow a BW attack. The indirect payoff is that effective products against BW deter employment and proliferation of BW capabilities by hostile forces and bolster the confidence of the fighting force. Near-term opportunities for transition to advanced development include a first generation vaccine to protect against lethal effects of staphylococcal enterotoxin B (SEB); mid-term transition opportunities include a vaccine to protect against lethality produced by ricin and botulinum toxins and *Yersinia pestis* (plague), as well as a second generation SEB toxin vaccine to protect against both lethality and incapacitation. In the long term, vaccines effective against filoviruses (e.g., Ebola virus) will be transitioned.

3.3.2 Subarea Overview

3.3.2.1 Goals and Timeframes. The goal of the Medical Biological Defense Research Program is to ensure the sustained effectiveness of U.S. forces in a BW environment. The objectives are:

- To prevent casualties by use of medical countermeasures, e.g., vaccines, toxoids, and pretreatment drugs;
- To diagnose disease with forward deployable kits and confirmation assays; and
- To treat casualties, to prevent lethality, and to maximize return to duty using antitoxins and therapeutic drugs.

Current prophylaxes are inadequate since they do not cover all agents, immunization schedules are too long, no approved diagnostic kits exist, and specific treatment is extremely limited.

3.3.2.2 Major Technical Challenges. Major technical challenges include appropriate model systems for investigational purposes, generation of immune responses to small molecules, and expression vectors for recombinant products.

3.3.2.3 Related Federal and Private Sector Efforts. There is little interest in medical biological defense S&T in the private sector or in Federal organizations outside of the three Services because identified BW threats are of little general medical interest and because extensive Congressionally mandated safety measures that are required in order to work with these agents are burdensome. The research program includes 5 CRDAs, 4 Small Business Innovative Research (SBIR) contracts, and 29 contracts with universities in the United States and abroad. There are also 4 small contracts with other government agencies (Veterans Administration and the Army Research Office) and non-profit organizations in the United States. A recent NIH review confirmed that the missions of the NIH and Medical Biological Defense Research Program are unique and distinct, and that there is no duplication of their efforts.

3.3.3 S&T Investment Strategy

Technology efforts are arrayed according to the validated medical threat agents that they address. The amount of effort is distributed to these threats in accordance with their impact on operations, the potential contribution of technology to overcoming each threat, the feasibility of achieving technology objectives through military investment, and the need to maintain a technology base that is capable of responding to emerging threats and avoiding technological surprise.

3.3.3.1 Technology Demonstrations. Efforts focus on the development of medical countermeasures against the threats of ricin toxin and staphylococcal enterotoxin B (SEB). For ricin toxin, microencapsulation delivery systems for vaccine candidates will be evaluated and a second generation recombinant vaccine that will offer greater safety over toxoided components and an enhancement in protective immunity will be transitioned to advanced development in FY00. For SEB, initial *in vivo* preclinical studies to demonstrate efficacy and safety of a second generation recombinant vaccine candidate will be performed in FY96. Future efforts will focus on evaluation of cross protective capabilities or feasibility of a combined serotype vaccine candidate with a second generation vaccine, and on more extensive studies of safety, efficacy, stability, and production parameters in multiple models.

3.3.3.2 Technology Development. Medical countermeasure (e.g., vaccines, therapeutics and diagnostics) development efforts are arrayed into the following functional areas:

- Protein Toxins, including SEB, ricin, botulinum toxin, *C. perfringens* toxin, and venoms.
- Bacterial Agents, including *Y. pestis* (plague), Brucella (brucellosis), *B. anthracis* (anthrax), *C. burnetii* (Q-fever), *V. cholerae* (cholera), *F. tularensis* (tularemia), *B. mallei* (glanders), and *R. prowazekii* (typhus).
- Viral Agents, including encephalomyelitis viruses, variola (smallpox), and filoviridae (e.g., Ebola virus).
- Neuroactive Compounds, including sodium channel neurotoxins, peptide ionophores, and other physiologically active biological substances.
- Diagnostics, including confirmatory diagnostic tests and diagnostic reagents.

3.3.3.3 Basic Research. Basic research focuses on biochemical, immunological and/or microbiological characterization of the etiologic agent, pathogenesis of disease, the protective host immune response, and finding suitable *in vitro* and *in vivo* models of infection and injury.

3.4 Medical Chemical Defense

3.4.1 Warfighter Needs

Medical Chemical Defense technologies are essential to protect and sustain U.S. forces during a chemical warfare (CW) attack and to provide the world's best chemical casualty care. Medical Chemical Defense provides medical countermeasures directed against CW threats. These are developed through an understanding of the pathophysiology of threat agents. An example of an opportunity for technology transition to advanced development in the mid-term is the Medical Countermeasures Against Vesicant Agents, which will sustain warfighting capability by preventing or decreasing the incidence of vesicant agent injuries, reducing the severity of the resulting injuries, minimizing incapacitation, and decreasing the substantial burden that such injuries place on the medical treatment system. Also in the mid-term, a reactive Topical Skin Protectant (rTSP) will be transitioned to advanced development; this product will provide a barrier to protect the skin from chemical warfare agents, and simultaneously detoxify the agents. This medical countermeasure will function as a supplement to the Mission Oriented Protective Posture chemical protective ensemble. In the mid-long term, a reactive/catalytic scavenger pretreatment will be transitioned to provide extended protection against nerve agents, without performance-reducing side effects or the need for extensive post-exposure therapy; this will increase operational flexibility. In addition to their personnel protective effects, effective medical countermeasures against CW threats may provide the additional benefit of deterring the use of these weapons.

3.4.2 Subarea Overview

3.4.2.1 Goals and Timeframes. The mission of the Medical Chemical Defense Research Program is to preserve combat effectiveness by timely provision of medical countermeasures in response to joint service CW defense requirements. This mission is accomplished via three goals: maintain technological capability to meet present requirements and counter future threats; provide individual level prevention and protection to preserve the fighting strength; and provide medical management of CW casualties to enhance survival and expedite and maximize return-to-duty.

3.4.2.2 Major Technical Challenges. Major technical challenges include developing effective pretreatments completely devoid of side effects, developing suitable animal models, extrapolating efficacy test results from animals to man, and generating immune responses to small molecules.

3.4.2.3 Related Federal and Private Sector Efforts. Within the Medical Chemical Defense Research Program there are 42 active CRDAs. Three SBIR contracts support activities within the research program, as do the 50 extramural research and development contracts with government agencies, universities, nonprofit organizations, and industry both in the United States and in other countries (the Netherlands and Israel).

3.4.3 S&T Investment Strategy

Technology efforts are arrayed according to the medical threat agents that they address. The amount of effort is distributed to these threats in accordance with their impact on operations, the potential contribution of technology to overcoming each threat, and the feasibility of achieving technology objectives through military investment.

3.4.3.1 Technology Demonstrations. Efforts focus on the development of medical countermeasures against threats from nerve and vesicant agents. For nerve agent countermeasures, the demonstration of safety and efficacy sufficient for a Milestone 0 transition of an advanced anticonvulsant component for soldier/buddy-use nerve agent antidote is planned for FY96. For the vesicant agent sulfur mustard (HD), the demonstration of safety and efficacy of a candidate medical countermeasure sufficient for a Milestone 0 transition is planned for FY99.

3.4.3.2 Technology Development. Medical countermeasure development efforts are arrayed into the following functional areas:

- Vesicant Agent Countermeasures, focusing on therapeutic drugs for HD.
- Nerve Agent Countermeasures, focusing on an advanced anticonvulsant and biological prophylactic approaches.
- Skin and Patient Decontamination, focusing on a reactive topical skin protectant.
- Chemical Casualty Management, focusing on diagnosis, prognosis, treatment and disposition of chemical casualties.

3.4.3.3 Basic Research. Basic research focuses on chemical and biochemical characterization of agent interactions with biological target molecules, characterization of molecular and cellular mechanisms of pathogenesis, and identification and development of suitable *in vitro* and *in vivo* models of injury.

3.5 Military Operational Medicine

3.5.1 Warfighter Needs

Military Operational Medicine addresses the full range of threats and challenges known to limit human effectiveness. These threats and challenges span such diverse issues as deployment and combat stress as well as gender differences in response to high G forces during tactical flight operations. Research elements share a common goal of reducing the human costs of National Security operations through an effort encompassing operational hazards and materiel threats.

Efforts focusing on operational hazards utilize biomedical science to attain the broadest possible performance envelope for the warfighter. The range of individual operational circumstances includes arctic to desert environments, stationary watch to operations beyond Mach 2, high altitude to deep diving and submarine operations, as well as shipboard operations to intense land combat. Stress is pervasive in battle; it claims one direct casualty for every four wounded and is contributory to one in five physical casualties. Neuroscience-based studies are designed to effectively extend an individual's capacity to withstand battle stress. Fatigue and sleep loss may account for 20% of all

injuries on the battlefield and are prominent factors in the degradation of military performance. Work in progress targets sleep as a manageable resource. A near-term impact of this research will be an operational doctrine for pharmacological interventions to counter fatigue and sleep loss; in the mid-term a joint guidance for planning and conducting sustained operations that optimize human performance will be fielded. Heat and cold restrict human performance. Biomedical technologies are applied to improve understanding of the mechanisms of heat and cold injury and to reduce the operational impact of these and related environmental challenges. In the long term, biological means to modify environmental injury will be developed. Demands of modern warfare continue to outstrip the information processing capacity of the human nervous system. The goal is to maximize the effectiveness of human operator capabilities and hardware performance. These initiatives combine to enhance military power and effectiveness and to reduce casualties, whatever the mission. They form the core of medical efforts to protect the lives, safety and capabilities of individual warfighters and system operators.

Hazards from military systems and operations regularly challenge the health and safety of military personnel. The potential for death, injury or performance degradation is systematically explored for hazards ranging from munition exhaust gases and blast effects to the mechanical strains and jolts associated with operational platforms. Systems and operations threats, either singly or in combination, are detailed and individual exposure criteria are established. Materiel developers are supported with specialized databases and evaluations to ensure that affordable, realistic efforts are directed at minimizing risk to tomorrow's warfighters. For example, the application of safe frequency and power exposure standards, to be developed in the near term, will guide laser and electromagnetic radiation system developers away from harmful frequency/power mixes. This simultaneously opens safer regions of the spectrum to use of higher power for greater range and effectiveness. Biomedical information is critical to development of frequency agile laser eye lenses that will afford effective protection against deliberate and accidental laser eye injury and will be of special importance to aviators. This program represents an active partnership between biomedical scientists and materiel developers that seeks affordable options for ensuring both system safety and operational effectiveness.

3.5.2 Subarea Overview

3.5.2.1 Goals and Timeframes. War remains a test of the individual's will both to endure and to master potentially overwhelming conditions. Thus, the inherent challenge facing the warfighter, evolves with the development of operational doctrine, materiel systems, and mission scenarios. The objectives are:

- Develop and promote biomedical contributions to operational readiness;
- Sustain the health and performance of operational warfighters;
- Provide the bases for scientifically sound doctrine for optimizing recovery following stress; and
- Quantify the combined effects of multiple diverse stressors in support of improved operational concepts, tactics, and doctrine.

3.5.2.2 Major Technical Challenges. Major technical challenges include pharmacological control of restorative sleep and alertness; neurophysiological control of

spatial disorientation and motion sickness; stress-induced immune suppression; enhanced cognitive and physiological function during intense, prolonged stress; and psychophysiological adaptations for man-machine interface of electro-optical displays and automated command consultation systems.

3.5.2.3 Related Federal and Private Sector Efforts. Industry and academic partnerships are so woven throughout the program that scientific publications without co-authorship from outside are rare. Opportunities to divest commitments are pursued aggressively. However military laboratories possess unique equipment, and have access to deployed forces and environments that can be fully exploited only by DoD uniformed scientists who have the operational experience to conduct key aspects of the research. Major Government agencies include the Department of Health and Human Services; Veterans Administration; NASA; National Science Foundation; Department of Transportation; National Toxicology Program; and Department of Energy National Laboratories. Contractors/ Industry Partners include universities; non-profit organizations; private industry; foreign organizations; Small Business Initiatives; 26 CRDAs; and 7 Consortia.

3.5.3 S&T Investment Strategy

In executing the Military Operational Medicine Research Program, technology efforts are arrayed according to the medical threats that they address. Distribution of investment among these threats is in accordance with their impact on operations, the potential contribution of technology to overcoming each threat, and the feasibility of achieving technology objectives through military investment.

3.5.3.1 Technology Demonstrations. Advanced Medical Technology (Field Medical Support) is being jointly supported by both the Military Operational Medicine and the Combat Casualty Care subareas. In support of the Military Operational Medicine mission, integration of a set of noninvasive physiological sensing technologies will be demonstrated that can enable situational decision-making by commanders based on real-time knowledge of the individual and collective physical capability of deployed personnel. These sensing capabilities also have applications to trauma care; the medical application of these technologies are described within the Combat Casualty Care subarea. Additional efforts will assess and validate the value of tactile (vibratory) stimulators in augmenting currently available cues across a representative range of simulated and operational training environments. Use of such stimuli has potential to reduce spatial disorientation accidents in the military, and to improve navigation and awareness of target locations for sonar/radar operators. Efforts are currently focused on selection of appropriate signal transducers with several options available; a flight test of an improved vibrotactile prototype is planned in FY97.

3.5.3.2 Technology Development. Efforts are arrayed into the following functional areas:

- Operational Medicine and Human Performance, including medical assessment for selection and classification of personnel, effects of sustained and continuous operations, sleep and performance, operational stress, visual performance, spatial orientation, physical fitness and endurance, musculoskeletal injuries and physical performance, nutrition, safety of flight, and noise.

- Biodynamic (Biomechanical) Stress, including effects and guidelines to reduce the hazards of maneuvering acceleration, abrupt acceleration and impact, vibration and motion, and repeated impact jolt; auditory and whole-body blast bioeffects; and noise effects.
- Physiology in Extreme Environments, including heat and cold stress, high altitude effects (both terrestrial and aerospace), immersion and hyperbaric stress.
- Non-ionizing Radiation Bioeffects, including laser bioeffects and effects of radiofrequency and electromagnetic radiation.
- Health Effects of Toxic Hazards, including occupational toxicology and health risk assessment, and environmental effects of military toxic hazards.

3.5.3.3 Basic Research. Basic research focuses on development of *in vitro* and *in vivo* models for risk assessment and the evaluation of physiological responses to operational stressors, development of animal behavioral models of human performance, and identification of humoral and other mediators of responses to operational stressors.

3.6 Military Dentistry

3.6.1 Warfighter Needs

Dental disease is an ever-present decrement to military readiness. Historically, dental disease and maxillofacial trauma cause 10-20% of all evacuations among deployed personnel. A substantial effort to prevent these casualties requires dental manpower not available in the military's dental corps. Military dental research focuses on military-specific needs, namely, eliminating troop evacuations due to dental disease and on decreasing the morbidity and mortality due to maxillofacial trauma. It provides the only avenue to develop improved readiness by either preventing dental emergencies or by faster, easier and more effective far-forward treatment of those that do occur in order to eliminate evacuations. Near-term opportunities for transition to advanced development include predictive diagnostic tests for oral pathogens, microencapsulated antibiotics to protect wounds against infection, more effective diagnostic capability using portable digital imaging systems and better geographical capabilities via teledentistry. Mid-term transition opportunities include materiel development and improved storage capabilities that will extend the utility of expensive pre-positioned dental supplies and ultra-long acting local anesthetics that will further limit or delay evacuation requirements. Long-term transition opportunities include new anesthetics that will selectively control pain without interfering with myelinated neurons responsible for motor and touch functions and novel sustained release pharmaceuticals that will prevent dental emergencies among deployed personnel.

3.6.2 Subarea Overview

3.6.2.1 Goals and Timeframes. The ultimate goals of military dental research are to eliminate patient evacuation due to dental disease and to decrease the morbidity and mortality following maxillofacial trauma. More specifically, in the area of predictive diagnostics, goals are to identify and treat likely casualties in advance of deployment. In

the area of far-forward diagnostics and therapy, goals are to develop better means of far-forward diagnosis using a filmless hand-held X-ray device and/or teledentistry consultations. Other goals include completing a dental database of dental care needs in recruits, improving ways to control pain and prevent wound infection and develop improved and more storage stable dental materials.

3.6.2.2 Major Technical Challenges. Major technical challenges include an incomplete knowledge of safe, effective anti-plaque agents and the ability to sustain long-term protection from disease causing oral bacteria; the absence of optimal reconstructive surgical procedures (including surgical robotics capability) to restore form and function of the jaw following massive maxillofacial trauma; and an incomplete knowledge of ways to stimulate bone formation and control bleeding in large bony defects.

3.6.2.3 Related Federal and Private Sector Efforts. In April 1994, a Joint Services Dental Rebuild Conference Special Review and Analysis was conducted over a 2-day period in which the entire Army and Navy Dental Research and Development Program was reviewed by a blue ribbon panel including representatives from the National Institute of Dental Research, NIH. The mission-specific orientation of the military dental research effort was confirmed and no duplication of effort was found among Army, Navy, and NIH programs

3.6.3 S&T Investment Strategy

Technology efforts are arrayed according to validated deficiencies identified by the requirements sponsors. In turn, investment in these efforts are correlated with the technological ability to solve the problem, the impact the solution will have on the deficiency, and due to a restricted budget, the cost associated with the research effort.

3.6.3.1 Technology Demonstrations. Wound sepsis increases morbidity/mortality in 20-35% of all war casualties and deaths from resistant strains are increasing in hospitals worldwide. A single dose therapy technology that sustains release of antibiotics from polymeric, biodegradable microspheres, when applied directly into wounds, has been shown to have improved efficacy over conventional systemic antibiotic therapy. This technology is now mature, and ready for Investigational New Drug (IND) preparation/clinical trials.

3.6.3.2 Technology Development. Efforts are arrayed into the following functional areas:

- Maxillofacial Trauma Care, including antibiotic development; local anesthetics; bone repair devices, materials, and methodologies; and diagnostic devices.
- Dental Disease and Dental Emergencies, including evaluation of dental materials, equipment, drugs, and procedures; periodontal disease diagnosis, prognosis, and prevention; patient and dental records management systems; and dental epidemiology.

3.6.3.3 Basic Research. Basic research focuses on initial formulation of candidate antibiotic and anesthetic delivery systems, development of models for drug discovery and evaluation, causative mechanisms in the pathogenesis of periodontal diseases, and identification of candidate diagnostic markers of oral disease.

3.7 Medical Radiological Defense

3.7.1 Warfighter Needs

With the growing risk of nuclear proliferation through clandestine nuclear programs, the threat of the use of a nuclear weapon or other radiation weapons is more severe than ever. Because it is likely that military missions will have to be conducted in radiation environments, the development of prophylactic and treatment protocols and knowledge of the health risks are essential to permit safe military operations in a radiation environment. Because exposure to radiation well below lethal levels can significantly alter the immunological status of the service member, it is essential that both risk assessments and medical countermeasures consider the combined insult of radiation exposure and other battlefield toxins, especially biological and chemical warfare agents.

Prevention of incapacitating and lethal ionizing radiation injuries will enable mission continuation and accomplishment in the nuclear or radioactive combat environments. Accurate casualty prediction models, particularly in combined Nuclear/Biological/Chemical (NBC) environments, are required for effective command decision making and force structure planning to ensure mission success. An advanced biological dosimetry methodology is required for reliable determination of individual radiation exposure(s) for triage, treatment decisions and long-term risk assessment. Anticipated increases in use of depleted uranium (DU) munitions are expected to produce a significant number of casualties wounded with such weapons; DU research will ensure that service personnel receive optimal treatment to mitigate risks from DU exposure and protect them and their offspring.

Potential payoffs include the development of improved therapeutic strategies for the treatment and prevention of both early and long-term health effects from radiation exposures, cost-effective and rapid health risk assessment through automated biodosimetry and disaster preparedness planning.

3.7.2 Subarea Overview

3.7.2.1 Goals and Timeframes. The goals of the program are to develop prophylactic and therapeutic approaches to radiation injury alone and combined with other battlefield toxicants, and to define human health risks associated with operational radiation exposures. Specific sub-goals and timeframes are as follows:

- Radiation Prophylaxis: To develop drug regimens that can be given prior to or shortly after exposure and will protect personnel from the adverse health effects of acute and chronic exposures to ionizing radiation. First generation prophylactic agents will be identified by FY97 with improvements each subsequent year.
- Assessment: To (1) estimate and model human health risks in low-dose/low-dose rate exposures characteristic of the fallout fields from nuclear weapons and reactor accidents (FY99); (2) define the most important interactions of radiation with other toxicants (FY98-02); and (3) develop an advanced biological dosimetry system with the sensitivity to provide definitive dose assessments for acute, protracted, and multiple exposures (FY98). An advanced high dose dosimetry methodology will be fully developed in FY98 followed by a low-dose system in FY01.
- Radiation Injury Treatment: To develop protocols for the treatment of injuries from radiation alone or in combination with other battlefield injuries (FY01).

3.7.2.2 Major Technical Challenges. Major technical challenges include development of protective and therapeutic drugs with minimal performance impairing side effects, extrapolation of animal model results to humans, development of routine, low cost biodosimetric assay to monitor radiation exposure, establishing experimental chronic exposure methodology and model development for combined injury studies.

3.7.2.3 Related Federal and Private Sector Efforts. NASA has a radiation program funded at a level of about $4 million annually, with most research focused on the biological effects of cosmic rays. The National Cancer Institute, through its Chemical and Physical Carcinogenesis Program, provides about $20 million for basic radiation research and for epidemiological studies in the U.S. and the former Soviet Union. A separate program at the National Cancer Institute (Extramural Radiation Research Program) provides about $45 million for basic and radiotherapy-related research on ionizing radiation. The DOE funds basic radiobiology research at a level of approximately $5 million. The Nuclear Regulatory Commission funds approximately $1 million on modeling and prediction of effects of reactor accidents.

3.7.3 S&T Investment Strategy

3.7.3.1 Technology Demonstrations. A multiple bioassay strategy will provide reliable radiation dose assessment for various radiation scenarios to assure proper medical treatment of radiation casualties. Use of one bioindicator endpoint has been validated for use in cases of high dose (3-10 Gy)/partial-body exposures. This has direct impact on current medical treatment decisions of bone-marrow transplant vs. cytokine and antibiotic therapy. A second assay, the conventional dicentric aberration, has also

been improved and is suitable for rapid and automated analysis. These biodosimetry service capabilities are now ready for implementation.

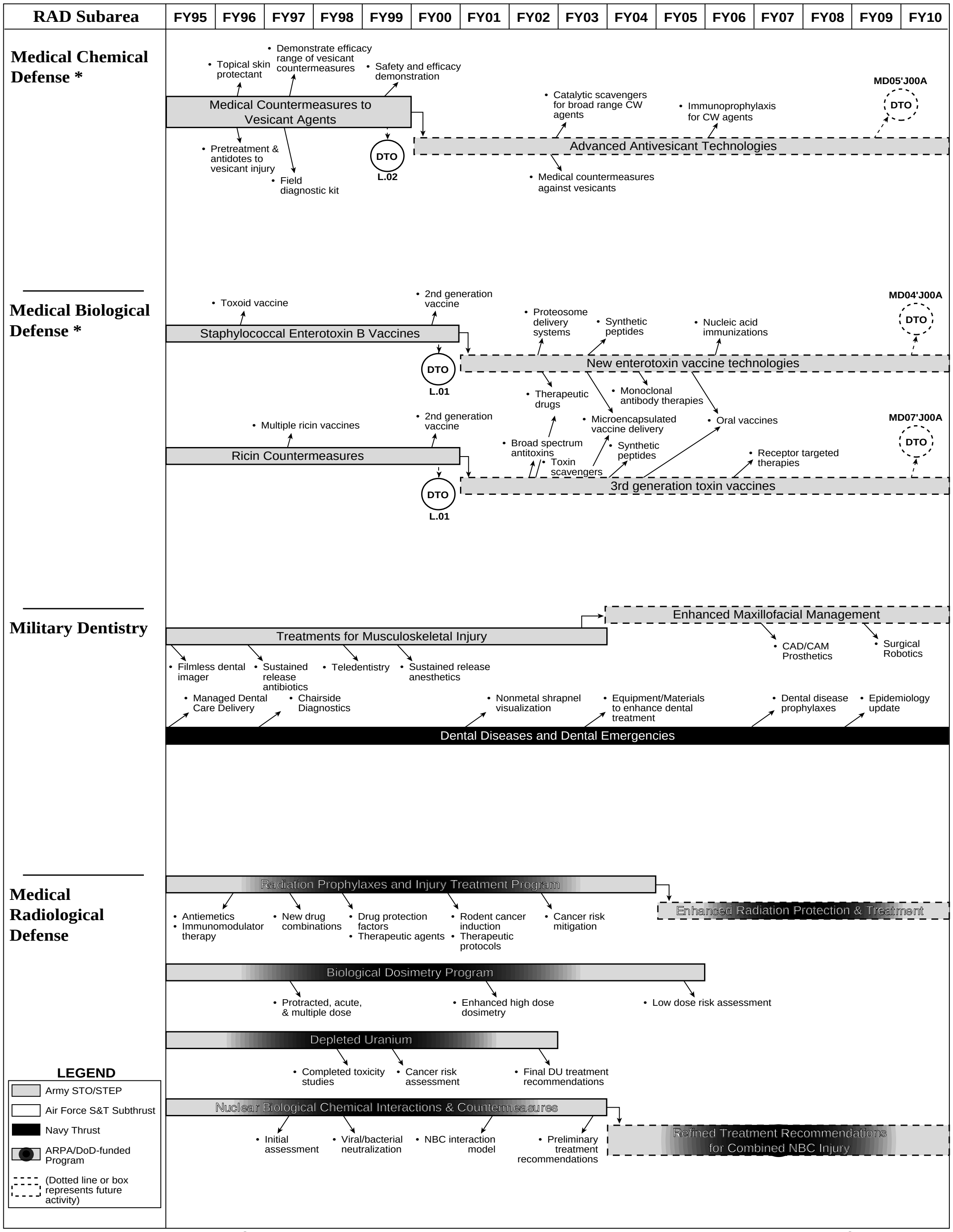
3.7.3.2 Technology Development. Efforts are arrayed into the following functional areas:

- Radiation Prophylaxis
- Assessment
- Radiation Injury Treatment
- Radiation Hazards in Aerospace Operations
- Delayed Radiation Effects

3.7.3.3 Basic Research. There are no basic research efforts in this subarea.

4.0 TECHNOLOGY AREA ROADMAPS AND RESOURCES

4.1 Technology Area Roadmaps - See Figure VI.4.



*** Not all supporting elements of DTOs L.01 and L.02 are shown. For a complete description, see the Joint Warfighting Science and Technology Plan, Chapter IV.L.**

Figure VI.4. Biomedical Roadmap

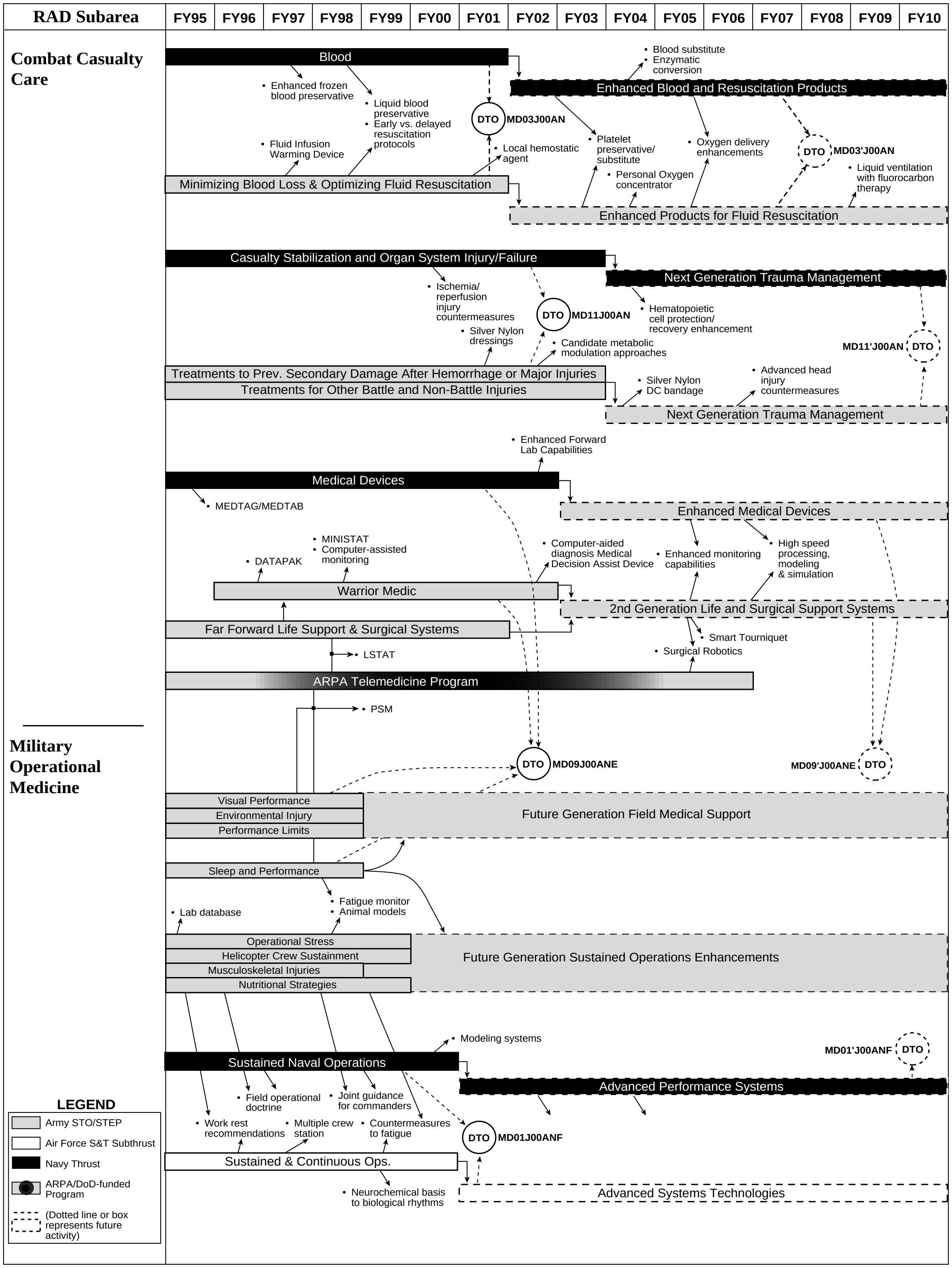


Figure VI.4. Biomedical Roadmap (cont.)

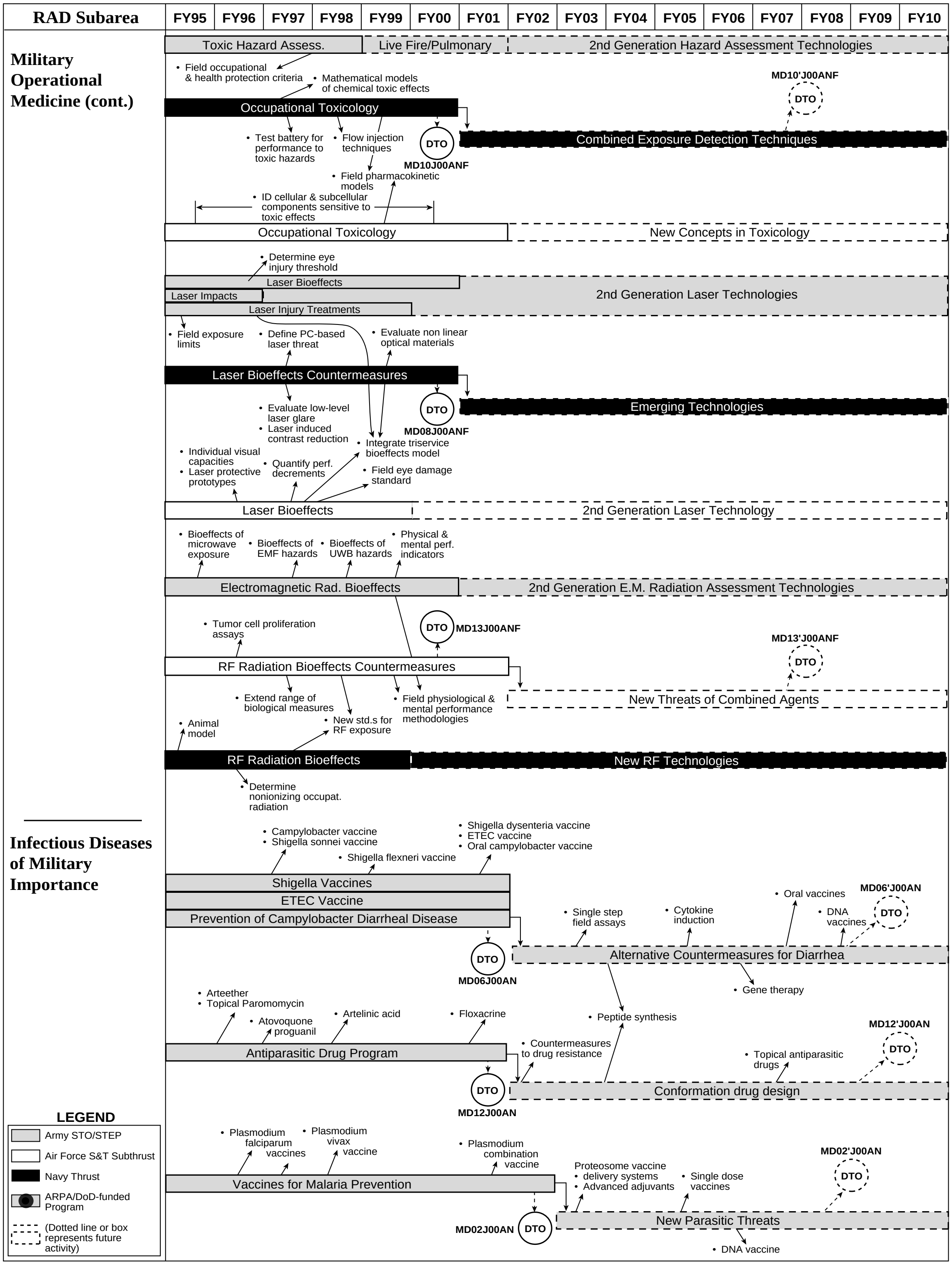


Figure VI.4. Biomedical Roadmap (concluded)

4.2 Biomedical Science and Technology Area Resources ($M)

DTOs	Program Element	$ in millions					
		FY96	FY97	FY98	FY99	FY00	FY01
MD01J00ANF SUSOPS Perf. Enhancement	0602787A	5.6	4.4	4.8	6.1	6.0	6.1
	0603002A	1.8	0	0	0	0.2	0.2
	0602233N	1.2	1.2	1.3	1.4	1.5	1.6
	0603706N	0.7	0.8	0.8	0.9	1.0	1.0
	0602202F	0.4	0.5	0.5	0.5	0.5	0.5
	DTO Total	10.7	6.9	7.4	8.9	9.2	9.4
MD02J00A Prevention of Malaria	0602787A	2.4	1.9	2.0	2.0	1.9	1.9
	0603002A	1.7	1.6	1.6	1.3	1.3	1.3
	DTO Total	4.1	3.5	3.6	3.3	3.2	3.2
MD03J00AN Blood	0602787A	1.5	1.4	1.2	1.3	1.3	1.3
	0603002A	0.8	0.8	0.8	0.8	0.8	0.8
	0602233N	0.9	0.9	0.9	1.0	1.0	1.0
	0603706N	4.9	5.1	5.2	5.4	5.6	5.7
	DTO Total	8.1	8.1	8.2	8.4	8.6	8.9
MD06J00A Diarrheal Disease	0602787A	1.5	1.4	1.7	1.3	1.2	1.2
	0603002A	1.3	1.3	1.3	1.3	1.3	1.3
	DTO Total	2.8	2.7	3.0	2.6	2.5	2.5
MD08J00ANF Laser Countermeasures	0602787A	1.3	1.2	1.3	1.5	1.5	1.5
	0602233N	0.2	0.8	0.8	0.9	0.9	1.0
	0603706N	0.3	0.5	0.6	0.6	0.7	0.7
	0602202F	1.0	0.9	0.9	0.9	0.9	1.0
	DTO Total	2.7	3.4	3.6	3.9	4.0	4.2
MD09J00ANE Field Medical Support	06002787A	3.3	4.2	4.5	4.5	4.3	4.5
	06003002A	0.5	0.6	0.5	0.6	0.6	0.6
	06003706N	2.6	3.5	3.6	3.8	4.0	4.2
	06002712E	27.0	26.7	31.2	37.7	44.4	48.5
	06003570E	3.5	0	0	0	0	0
	DTO Total	36.9	35.0	39.7	46.5	53.3	57.8
MD10J00ANF Toxic Hazards	0602787A	0.1	0.1	0.1	0.1	0.1	0.2
	0602233N	0.5	0.5	0.6	0.6	0.7	0.7
	0603706N	0.8	0.8	0.8	0.8	0.8	0.9
	0602202F	1.1	1.3	1.2	1.2	1.2	1.3
	DTO Total	2.4	2.7	2.6	2.7	2.8	3.0
MD11J00AN Trauma Mgmt/Treatment	0602787A	7.6	7.2	6.5	6.6	6.5	6.7
	0603002A	0.8	0.8	0.8	0.8	0.8	0.9
	0602233N	0.9	0.9	0.9	0.9	1.0	1.0
	0603706N	2.0	2.0	2.1	2.2	2.2	2.3
	DTO Total	11.2	10.9	10.3	10.5	10.6	10.8
MD12J00A Antiparasitic Drugs	0602787A	0.8	1.8	1.8	1.8	1.7	1.7
	0603002A	3.4	2.6	2.6	2.5	2.5	2.5
	DTO Total	4.1	4.3	4.4	4.3	4.2	4.2
MD13J00ANF RF Radiation Countermeasures	0602787A	1.1	0	0	0	0	0
	0602233N	0.3	0.3	0.4	0.4	0.4	0.4
	0603706N	0.5	0.5	0.6	0.6	0.7	0.7
	0602202F	1.0	1.1	1.1	0.9	0.9	0.9
	DTO Total	2.8	2.0	2.0	1.9	1.9	2.0
Non-DTO Supporting Elements	0602787A	1.1	0.5	0.6	0.6	0.6	0.6
	0603002A	0.1	0.1	0.1	0.1	0.1	0.1
	0603706N	0.4	0.4	0.4	0.4	0.4	0.5
	0602787D	7.9	8.5	9.3	10.3	10.6	10.9
	0603002D	3.3	3.5	3.1	2.3	2.4	2.5
	DTO Total	12.8	13.0	13.5	13.7	14.1	14.6

Figure VI.5. Biomedical Science and Technology Roadmap Resources

TOTALS MAY NOT AGREE DUE TO ROUNDING

BIOMEDICAL SCIENCE AND TECHNOLOGY ACRONYMS

21CFR	Code of Federal Regulations
ACTD	Advanced Concept Technology Demonstration
ASBREM	Armed Services Biomedical Research Evaluation and Management
ASD(HA)	Assistant Secretary of Defense, Health Affairs
ATD	Advanced Technology Demonstration
ATSD(NBC)	Assistant to the Secretary Defense, Nuclear/Biological/Chemical
BS&T	Biomedical science and technology
BW	Biological warfare
CDC	Centers for Disease Control and Prevention
CONUS	Continental U. S.
CPC	Chemical protective clothing
CRDA	Cooperative Research and Development Agreements
CW	Chemical warfare
DDR&E	Director of Defense Research and Engineering
DTO	Defense technology objective
DU	Depleted uranium
FDA	Food and Drug Administration
FY	Fiscal year
HD	Sulphur mustard
IND	Investigational new drug
NIH	National Institutes of Health
OCONUS	Outside continental U. S.
ODS/S	Operation Desert Shield/Storm
PSM	Personal Status Monitor
R&D	Research and development
RF	Radiofrequency
rTSP	Reactive topical skin protectant
SBIR	Small Business Innovative Research
SEB	Staphylococcal enterotoxin B

VII. FY 1997 DEFENSE TECHNOLOGY AREA PLAN FOR SENSORS, ELECTRONICS AND BATTLESPACE ENVIRONMENT

1. INTRODUCTION

1.1 Definition/Scope

This area develops and demonstrates technology for sensors, electronics and battlespace environment which were addressed in individual Technology Area Plans (TAPs) previously. The Sensors, Electronics, and Battlespace Environment area addresses fourteen Subareas: Radar Sensors, Electro-Optic Sensors, Acoustic (including Magnetic and Seismic) Sensors, Automatic Target Recognition, Integrated Platform Electronics, Radio Frequency (RF) Components, Electro-Optics, Microelectronics, Electronics Integration Technology, Electronic Materials, Terrestrial Environment, Ocean Environment, Lower Atmosphere Environment, and Space/Upper Atmosphere Environment (See Figure VII.1). This area provides sensor technology which has application including strategic and tactical surveillance, identification and targeting of threats from all military platforms including satellites, aircraft, helicopters, ships, submarines, ground vehicles and sites, unmanned air vehicles, unattended ground sensors and the individual soldier. In addition, this area encompasses the research and development, design, fabrication, and testing of: electronic materials; digital, analog, microwave, opto-electronic, and vacuum devices and circuits; and electronic modules, assemblies, and subsystems. Finally, this area provides for the study, characterization, predication, modeling, and simulation of the terrestrial, ocean, lower atmosphere, and space/upper atmosphere environments to understand their impact on personnel, platforms, sensors, and system; enable the development of tactics and doctrine to exploit that understanding; and optimize the design of new systems. See Resource Appendix for funding of this Defense Technology Area.

In the material that follows only <u>some</u> of the key objectives of the science and technology programs in sensors, electronics, and battlespace environment are explicitly described. This represents 57% of the total program which is also addressing many other objectives just as important to the DoD in the areas of sensors, electronics, and battlespace environment. In addition most of the demonstrations described below were enabled by earlier science and technology efforts. For example, DTO SE.19.01.ANF (Compact High Power RF Transmitters) was enabled by the development of the microwave power module (MPM) which is two and a half times more powerful, ten times smaller, and one third as costly as current technology. In turn the MPM was possible only because of the solely DoD supported efforts in GaAs materials development and MMIC technology. Similarly, the science and technology foundations for future demonstrations are being laid by the current science and technology programs much of which is not described below.

1.2 Strategic Goals

The vision for this area is provide the military with perfect situational awareness of the expanded battlefield in all environments to enable the warfighters to assess the scope and intent of the enemy and develop superior tactics for responses for achieving whatever political/military goal is selected. Investment in this area ensures that the U.S. will continue to maintain the warfighting "edge" through all-weather, day-night surveillance, precision targeting, and damage assessment; detection and tracking of difficult targets such as cruise missiles, anti-ship missiles, ballistic missiles, and submarines; and positive target ID. In addition this must be accomplished at an affordable cost in a diminished production base.

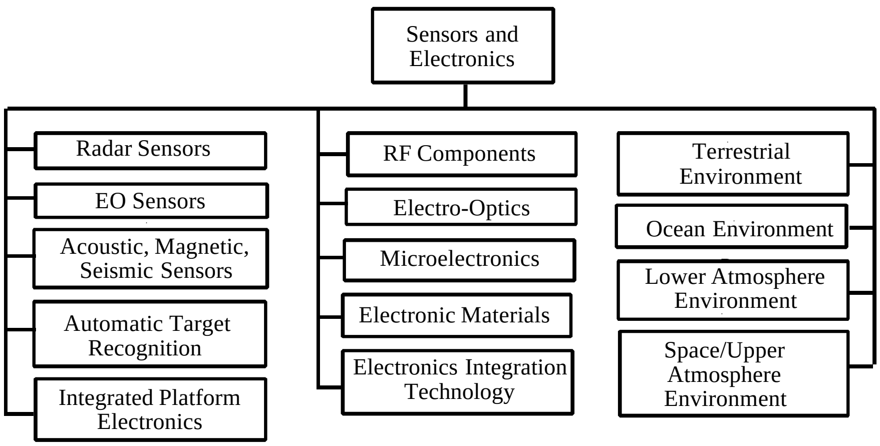


Figure VII.1. Planning Structure - Sensors, Electronics, and Battlespace Environment

Examples of specific goals include 50% reduction in cost of imaging radar and infrared search and track sensors; 5:1 improvement in thermal sensitivity of infrared detector focal plane arrays; 100:1 improvement in the false alarm rate and search rate of automatic target recognizers; 0.1 micro size electronics to enable orders of magnitude increase in the amounts of information that can be processed in a shorter time; development of ultra-compact microwave and millimeter wave modules that are 50 - 100% more efficient to enable new concepts in unmanned airborne vehicle radars, electronic decoys, and ultrahigh capacity communications; micromechanical systems for highly miniaturized sensors; ten times improvement in generating digital topographical data needed by the commander for optimization of deployment of forces; high resolution, longer term weather and sea state forecast for incisive decision making and enhanced operational capability in adverse weather; and a 90% improvement in capability to predict magnetic storm induced outages of command, control, communications, surveillance, and navigation systems.

1.3 Acquisition Warfighting Needs

Sensors and electronics technologies provide the foundation for the "eyes and ears and brains" for nearly all decision making systems, tactical and strategic weapons systems, and the intelligence community. They represent the key to force multiplication (the ability of a minimum number of U.S. platforms and personnel to defeat a much larger enemy force) and their continued advancement is critical to the avoidance of technological surprise on the battlefield by enabling comprehensive intelligence

gathering and total situational awareness over the extended battlespace. Critical to the development and operation of the DoD's information gathering capabilities is the complete understanding of the environment in which these sensors operate and the impact of that environment on the operation of the sensors to enable the U.S. forces to optimize their sensors and tactics to utilize the entire battlespace and its environment.

Consequently, the various subareas in sensors, electronics, and battlespace environments are addressing key requirements/needs identified in the Joint Warfighter Science and Technology document. As Figure VII.2. shows, these technologies are particularly critical to the needs/capabilities associated with dominant battlespace knowledge, precision force, combat identification, and joint theater missile defense. In addition, the pervasive nature of electronics technology to all aspects or military operations is clear from Figure VII.2.

Joint Warfighter S&T / Sensors & Electronics Subareas	Dominant Battlespace Knowledge	Precision Force	Combat Identification	Joint Theater Missile Defense	Military Operations in Urban Terrain	Joint Readiness	Joint Countermine	Electronic Warfare	Information Warfare	Chem. & Bio. Warfare Detection	Real-Time Logistics Control	Counter-Proliferation
Radar Sensors	●	●	●	●	○	◒	◒	◒	◒			◒
EO Sensors	●	●	●	●	●	◒	◒	○	◒	◒		◒
Acoustic Sensors	●	○	●	○	○	◒	◒					
ATR	●	●	●	◒	◒							◒
IPE	●	◒	◒	◒	○			●	●			
RF Components	●	◒	●	●	◒	◒	●	●	●			
EO Technology	●	●	●	●	◒			◒	○	○		●
Microelectronics	●	●	●	●	●	●	●	●	●	●	◒	●
Electronic Materials	●	●	●	●	●	●	●	●	●	●	◒	●
Electronics Integ. Tech.	●	●		●	●	○	○	●	●	○	○	●
Terrestrial Env.	●	◒	○	◒	●	●	◒	○	●	○	○	●
Ocean Env.	●	○	●	○	○	◒	●			○		
Lower Atmosphere	●	●	○	●	●	●		○	○	●	○	◒
Space/Upper Atmos. Env.	●	●	◒	◒	◒	●		●	◒	◒		◒

● Strongly Supports ◒ Moderately Supports ○ Marginally Supports

Figure VII.2. Connectivity of Joint Warfighter S&T to Sensors, Electronics & Battlespace Environment Technology Area

2. DEFENSE TECHNOLOGY OBJECTIVES (DTOs)

SE.01.01.ANF	Multi Mission UAV Sensor ATD
SE.02.02.N	Smart Skins Array ATD
SE.03.02.N	High Frequency Surface Wave Radar (HFSWR) ATD
SE.04.01.ANFE	Penetrating/Identification Radar
SE.05.01.ANFE	Affordable and Enhanced Radar Signal Processing
SE.06.01.A	Air/Land Enhanced Reconnaissance and Targeting ATD
SE.07.02.ANF	Advanced Pilotage
SE.08.02.A	Target Acquisition ATD
SE.09.02.A	North Finding Module
SE.10.02.NF	EO Sensor, Fusion, and Targeting
SE.11.01.ANFE	Advanced Infrared Search and Track (IRST) Systems
SE.12.02.ANF	Multi-Wavelength Multi-Function Laser
SE.13.03.NF	Aircraft Signature Measurement/Modeling Technology
SE.14.02.N	Lightweight, Broadband Variable Depth Sonar (Acoustic, Mag., Seismic)
SE.15.01.ANE	Sensor Signal Processing Technology (Acoustic, Magnetic, Seismic)
SE.16.01.NE	Active/Passive Sensor Technology (Acoustic, Magnetic, Seismic)
SE.17.02.ANFEC	ATR Dominant Target ID
SE.18.01.ANFE	Integrated Platform Avionics Demonstration
SE.19.01.ANF	Compact High Power RF Transmitters
SE.20.01.ANFE	Affordable Multi-Chip Modules for Phased Array Antennas
SE.21.01.AFE	Low Power Consumption RF Electronics
SE.22.01.ANFE	Advanced Infrared Focal Plane Array
SE.23.01.E	Militarized Flat Panel Display Technology
SE.24.01.ANF	Optical Control of Radar, Communication and Electronic Warfare Syst
SE.25.01.NFE	High Performance Microelectronics for Signal Processing and Computing
SE.26.01.AFH	Radiation Resistant Microelectronics
SE.27.01.E	Microelectromechanical Systems
SE.28.01.FE	Integrated Design Environment Technology
SE.29.01.FE	Electronic Module Packaging & Interconnect Technology
SE.30.01.ANFE	Energy Storage and Distribution Technology
SE.31.01.A	Digital Terrain Data Generation, Manipulation, and Standardization
SE.32.01.ANE	Warfare Support in the Littoral Battlespace
SE.33.01.ANF	Combat Weather Support
SE.34.01.A	Smoke, Obscurants, and Camouflage
SE.35.01.ANF	Electro-Magnetic & EO Propagation in Lower Atmosphere
SE.36.01.F	Specification of the C^3I Battlespace Environment

C05	Combat ID ACTD
D06	Cruise Missile Defense Phase I Detection ACTD
D07	Cruise Missile Defense Phase II Detection ACTD

3. TECHNOLOGY DESCRIPTION

3.1 Radar Sensors

3.1.1 Warfighter Needs

The radar sensors programs directly support JWS&T areas Dominant Battlespace Knowledge, Precision Force, Combat Identification and Joint Theater Missile Defense Capabilities by offering potential for "near-perfect", real-time knowledge of the enemy; to engage regional forces promptly in decisive combat, on a global basis; and to counter the threat of future ballistic and cruise missiles. Important objectives include near-leak-proof theater and ballistic missile defense; heightened ability (30 dB improvement) to detect low-RCS targets using Surface Based and Airborne WAS sensors; breakthrough capabilities to detect and classify foliage-concealed, time-critical targets as well as underground targets; development of affordable hardware (<$200K/copy) to provide decisive target acquisition/fire control capabilities for armored vehicles and an increase in radar instantaneous bandwidth (to 1 Ghz and beyond) to achieve improved Combat ID (target classification/identification) and tracking. Combat Identification (CID) provides for efficient accomplishment of the military objectives while minimizing fratricide. An effective CID capability must provide the required friend/hostile/neutral identification information at ranges compatible with the range of each platform's weapon. Service requirements for radar are moving beyond detection to target classification. This requirement for the Combat ID and automatic target recognition is now driving radar performance to high resolution, precisely registered n-dimensional measurement capability. Since cost reduction is an important aspect of all new DoD systems, significant use of Commercial Off-The-Shelf (COTS) equipment and novel Electronically Scanned (ESCAN) Antenna designs are being pursued. The Mountaintop Radar and the UHF/L Band Array Technology are targeted for transition to upgrades to the Navy E-2C and to the Air Force E-3 radars. The associated Space Time Adaptive Processing Algorithms, will have application to all airborne radars where nulling of clutter and jamming is required. The GBR Solid State Demo will be a major contributor to the National Missile Defense System. The low-frequency UWB radar and the Concealed Target Detection (CTD) algorithm programs lead to required capabilities in battlefield surveillance from platforms such as UAVs. Battlefield radar efforts provide upgrades to the Longbow Apache Fire Control Radar (FCR) as well as optimizing the specifications for the Comanche FCR system. The High Frequency (HF) Surface Wave and Ultra Wide Band (UWB) Technology are planned for transition to improve/upgrade the Navy's Surface Fleet Surveillance and Over-The-Horizon (OTH) Targeting Capabilities. Programs must demonstrate the benefits of combining radar and EO Sensors for significantly improving long-range, near all-weather, surveillance and target acquisition capability.

3.1.2 Radar Overview

3.1.2.1 Goals and Timeframes. The radar sensor can provide an all-weather, long-range detection, location and recognition of significant military targets capability. However, continued technology development is required to meet the needs of the warfighter. The goals of the Radar program are described below.

FY97	Develop/fabricate/test a shipboard high-frequency surface wave radar (HFSWR) that can detect low-flying anti-ship missiles at OTH ranges exceeding 20 nmi.
FY00	20dB improvement in clutter cancellation. 10X improvement in resolution.
FY03	Detection of targets in foliage, ground and buildings (90% PD).
FY05	Counter 1000 fold reduction in RCS. 75% cost reduction of radars.

Meeting these goals depends on advances in ATR (3.3), RF Components (3.6) Microelectronics (3.8), Electronic Materials (3.9) and Electronics Integration (3.10), as well as, understanding the Battlespace Environments (3.11, 3.13, 3.14).

3.1.2.2 Major Technical Challenges. The major technical challenge is to improve the capability of Radar Sensors while maintaining or reducing their size and weight, and significantly improve affordability, especially in an environment of declining quantities of weapons systems platform integration opportunities, hence sensor production base. For both imaging and non-imaging radars, advanced signal processing algorithms will be developed to address major challenges presented by clutter jamming and reduced cross-section targets and COTS hardware will be fully leveraged improve affordability. For multimode radars, the technical challenge is improved performances in all types of interference while at the same time maintaining affordability and minimizing radar cross-section of the sensor integrated onto its platform.

3.1.2.3 Related Federal and Private Sector Efforts. Advanced radar sensors are primarily developed for Government applications. Data from airborne space-based efforts are relevant to NASA and NOAA research efforts in weather detection, global change, atmospheric remote sensing, astronomy/astrophysics and orbital debris tracking along with numerous private sector spacecraft programs. Surface and airborne radar technology is applicable to the Department of Transportation, local and federal law enforcement agencies, the medical community and with multiple organizations for humanitarian purposes (i.e., search and rescue, buried mine and tunnel detection).

3.1.3 S&T Investment Strategy

The S&T Investment Strategy continues to focus on core technology development thrust areas that lead to Advanced Technology Demonstrations (ATDs) which, in turn, enables Advanced Concept Technology Demonstrations (ACTDs). Appropriate technology investments from other Government departments and agencies are incorporated. Particular emphasis is focused on affordability and integrated multi-sensor approaches.

3.1.3.1 Technology Demonstrations

3.1.3.1.1 Multi-Mission UAV Sensor ATD. DTO SE.01.01.ANF. An affordable, lightweight, multi-function radar will be built leveraging MIMIC technology for size and weight reduction and incorporate COTS signal processor for cost reduction. The ATD demonstrates an affordable, lightweight (60 pound), multi-function radar that will provide the battlefield commander with a continuous, real-time, all-weather

capability to detect, locate and identify high-priority fixed and mobile targets in all theaters of operation.

3.1.3.1.2 Smart Skins Array ATD. DTO SE.02.02.N This ATD demonstrates the technical feasibility, operational utility and support benefits of structurally embedded antenna arrays for the F/A-18. A leading edge embedded array will be demonstrated on an F/A-18 in FY 97.

3.1.3.1.3 High Frequency Surface Wave Radar (HFSWR) ATD. This ATD addresses DTO SE.03.02.N. The HFSWR will provide OTH, critical early warning (30 sec for M2.0 target) of low flying missiles and cue weapon engagement radars. Performance improvement goals include detection of supersonic sea skimming missiles at 2.5X the range currently achievable with a microwave radar with a better than 1.0 degree azimuth tracking accuracy.

3.1.3.1.4 Cruise Missile Defense (CMD) Phase II Technology Demonstration. The CMD phase II technology demonstration, DTO D07, is a follow-on to the joint Army-Navy CMD phase I ACTD, DTO DO6 (Mountaintop,) completed in February 1996. The CMD phase II will move the surveillance and fire control functions off the mountain and into an airborne platform. The focus will be on OTH detection and track of land and sea launched cruise missiles from airborne sensors and will enable surface-based air defense systems to engage there targets at ranges well beyond their radar horizon.

3.1.3.1.5 Combat ID. DTO C05. The joint Combat ID ACTD has been designed to demonstrate integrated air-to-ground and ground-to-ground combat identification capability. The approach employs an integrated CID architecture which combines data links with cooperative and non-cooperative identification capabilities. The resultant platform CID capabilities will be achieved by combining onboard data from multiple sensors and systems with indirectly-supplied off-board information. The ACTD will quantify the contributions of identification technologies in reducing fratricide and increasing combat effectiveness. The ACTD will refine inter/intra service tactics, techniques and procedures. Specific technologies included in the ACTD are: enhanced BCIS with a digital data link, a BCIS pod for fixed wing and rotary wing aircraft for point of engagement friend ID; enhanced forward air controller capability with integrated BCIS and Situation Awareness Data Link (SADL); modified SINCGARS SIP radios that will provide automatic target location query for friend ID; and situation awareness data from the digitized battlefield delivered to the gunner’s sight.

3.1.3.2 Technology Development

3.1.3.2.1 Penetrating/Identification Radar. DTO SE.04.01.ANFE. The Penetrating/Identification radar technology improves the warfighting capability through the development of ultra-wideband and narrow band radars and demonstration of radiometric technology that detects and identifies tactical targets hidden in foliage, buildings, or beneath the ground in real-time. Technology demonstrations will provide advances in clutter and interference rejection, target resonance and other identification phenomenology, and very low sidelobe imaging technologies. This technology also provides enhanced situation awareness capability by detecting targets in different mediums.

3.1.3.2.2 Affordable and Enhanced Radar Signal Processing. DTO SE.05.01.ANFE. The Affordable and Enhanced Radar Signal Processing effort develops low-cost (75% cost reduction) advanced signal processing techniques and radar architectures by highly leveraging commercial technology in hardware, software and operating systems. This advanced computing capability will improve SAR image formation and motion compensation, moving and stationary target discrimination, clutter rejection, target identification and all-digital radar front ends.

3.1.3.3 Basic Research. The basic research in new wide bandgap semiconductors, such as SiC and Group V nitrides, promise the potential for extremely high power, high efficiency amplifiers which could significantly drive down size, weight, volume and power requirements of radars thereby enabling more powerful, air-based radar systems. Progress in high temperature superconductors offers the potential for ultra-stable oscillators, channelized filters with extremely sharp cutoffs, and 20 bit, high speed A/D converters to enable radars with required dynamic range to handle the high environmental clutter of the littorals. Finally, a recent breakthrough in research offers, for the first time, the capability to perform real-time, true nonlinear filtering for target tracking.

3.2 Electro-Optics Sensors

3.2.1 Warfighter Needs

Fielding of superior electro-optical sensors will provide force multiplication in: dominant battlespace knowledge—addressed through high quality, long range imaging and non-imaging data from sensors digitally interfaced into the C^4I infrastructure; precision force—addressed through high resolution multi-spectral sensors for fire control systems, guided munitions, and aided target processing to drive battle tempo, high resolution/distributed sensors for large fields-of-view/regard and inexpensive ground vehicle day/night imagers; joint theater missile defense—addressed through long range passive infrared search and track; combat identification—addressed through multi-function and multi-sensor concepts; and military operations in urban terrain—addressed through land and littoral unattended, robotic and individual soldier multi-spectral sensors. Transition opportunities exist for all future military and commercial space systems. Aircraft applications include F-14, F-15, F-16, F-18, F-22, JAST, E2C, C-130, C-141, V-22, AH-64, Comanche, Kiowa Warrior and the AC-130 Gunship. Surface applications include, M1 Main Battle Tank and subsequent improvements, M2/M3 Bradley Fighting Vehicles, M8 Armored Gun System, Landing Assault Vehicle upgrades, AAAV, Future Scout Vehicle and TOW Missile System.

3.2.2 Electro-Optics Sensor Overview

3.2.2.1 Goals and Timeframes. The broad goals are to provide affordable sensors that enable US forces to maintain a decisive warfighting edge in performing tactical target detection, identification, acquisition, engagement, and mobility missions. These goals also provide the warfighter superior capabilities in the detection, discrimination and tracking of theater ballistic missiles. All performance goals are based on improving current levels of durability and life while paying particular attention to life-cycle cost of ownership.

FY96	Completion of IR window supersonic tests - 4X lifetime improvement Sea Test of Dual-Band Shipboard IRST
FY97	Achievement of 7X clutter rejection for F-14D IRST Demonstrate multi-function/multi-band laser 2-20 watt multiple wavelength output
FY98	Assessment of target ID methods for airborne application-90%PID @ 100km Demonstrate Ultra-wide (40 x 80 degree) night pilotage system Demonstrate reduced target acquisition timelines by a factor of four on ground combat vehicle
FY99	Demonstrate air-air & air-ground target ID at extended ranges (20 mi)
FY00	Concept demonstrator hi-res, 2000x2000 elements, 60 deg wide FOV, low-power IR imaging sensor
FY01	Demonstrate hyperspectral smart sensing
FY02	Completion of testing of multi-spectral detection & ID for deep hide targets (Pd>90%/Pfa<0.01/km2)

Meeting these goals depends on advances in electro-optics technology (3.7), Microelectronics (3.8), Electronics Integration Technology (3.10), Electronic Materials (3.9) and understanding the Battlespace Environments (3.11, 3.13 and 3.14).

3.2.2.2 Major Technical Challenges. The major technical challenges are to improve the capability of E-O Sensors and to reduce their size, weight, and power requirements while maintaining affordability. Specific challenges include: (1) active (laser-based) sensors - providing robust multi-functionality while maintaining compact size and low power requirements compatible with existing weapons system platform constraints; providing compact, efficient laser sources with substantial average powers at multiple wavelengths while accommodating eye safe operation; and development of two-dimensional laser detector focal plane arrays which combine each detector with its own amplifier/image processor for rapid, real-time 2 or 3 dimensional laser imaging. (2) individual soldier systems - development of lightweight, affordable system integrated optics, (3) multi-sensor systems - the use of shared or distributed aperture systems in order to control size to improve drag characteristics and cost; implementation of alternate sensing modes (e.g., polarization) to extract more scene information and reduce the dependence on spatial resolution; and signal processing to enable multi-function sensing and fusion of multiple sensors.

3.2.2.3 Related Federal and Private Sector Efforts. Advanced EO sensors are primarily developed for Government applications. Data from space-based efforts are relevant to and coordinated with NASA and NOAA research efforts in global change, atmospheric remote sensing, astronomy/astrophysics and orbital debris tracking along with numerous private sector spacecraft programs. Surface and airborne tactical technology are coordinated with the Department of Transportation (night driving, ship navigation), FAA (aircraft runway navigation and pilotage), local and federal law

enforcement agencies (surveillance, physical security), the medical community (diagnostics, human vision aids) and with multiple organizations for humanitarian purposes (search and rescue, buried mine detection). Industrial applications of thermal imaging technology involving calibrated measurement of temperatures is also leveraged.

3.2.3 S&T Investment Strategy

National investments are made to address warfighting needs and maintain US Force warfighting margin. Particular emphasis is paid to affordability, which is critical in an environment of lower weapon system quantities. Investment in multi-function sensors is also pursued where more than one battlefield capability can be provided through a single system, precluding the need for multiple systems.

3.2.3.1 Technology Demonstrations. The technology demonstrations entailed in E-O Sensors will illustrate enhanced situational awareness in an expanded battlespace and improved aircraft pilotage.

3.2.3.1.1 Air/Land Enhanced Reconnaissance and Targeting ATD. DTO SE.06.01.A. The ALERT ATD will demonstrate on-the-move, automatic aided target acquisition (detection range greater than 4000m at 180 kts) and enhanced identification via the use of a 2nd gen FLIR/multi-function laser sensor for application to future aviation and ground assets which do not have radar. Automation will extend the safe ingress rate by 50-75% for full threat coverage over manual acquisition. It will leverage AF and ARPA programs for search-on-the-move ATR and temporal FLIR processing. Demonstration will be real-time on a fully operational flying testbed emulation.

3.2.3.1.2 Advanced Pilotage. DTO SE.07.02.ANF. This effort will demonstrate improved night/adverse weather pilotage. Image intensification and 2nd gen thermal imaging will be demonstrated to yield a 50% improvement in resolution. A 25% increase in field of view will be demonstrated along with a dual spectrum system with a helmet mounted display. Low light level charged coupled device and advanced thermal imaging technology approaches (e.g., DTO Advanced Focal Plane Arrays) will be fused and tested for operations in a variety of light level conditions. Additional emphasis will be placed on presentation with a color helmet mounted display.

3.2.3.1.3 Target Acquisition ATD (TA ATD). DTO SE.08.02.A. Second generation thermal imaging, millimeter wave radar and a multi-function laser system providing range finding, target designation and target profiling (for ID) capabilities will be combined in a multi-sensor approach to extend the operational target acquisition range by 67% for exposed targets and 50% for partially exposed targets while reducing timelines 60-80% for tanks. User assessments will be made of the integrated hardware. Focus will be on upgrading existing Army and Marine M1 series tanks and planned Army tank upgrades.

3.2.3.2 Technical Developments. Key technical developments will result in capabilities for improved precision targeting, passive theater missile defense (TMD), and training safety.

3.2.3.2.1 North Finding Module. This area will fulfill DTO SE.09.02.A and will develop improvements in azimuth accuracy to allow full use of GPS data, target hand-off accuracy, and situational awareness. Accuracy of 5 to 10 mils will be demonstrated with initial measurements within three minutes (static) or one minute (moving).

3.2.3.2.2 EO Sensor, Fusion and Targeting. DTO SE.10.02.NF. This effort will capitalize on Service efforts in the areas of advanced sensors, multi-function/multi-spectral sensors and the fusion of these to result in enhanced targeting. User objectives will be addressed with the underpinning strategy of capitalizing on existing weapon system platforms for enhanced performance upgrades. This effort leverages DTO SE.17.02.ANFEC, Dominant Targeting Identification described in section 3.4 Automatic Target Recognition and section 3.7 E-O Sensors, subsection Advanced Focal Plane arrays.

3.2.3.2.3 Advanced Infrared Search and Track Systems. DTO SE.11.01.ANFE. This effort will develop IRST approaches for TMD and cruise missile/aircraft detection. Utilize advanced thermal sensors and digital signal processing technology, with multiple service capitalization on common components and subsystems. Ground vehicle focus is air-defense, on-the move operations. Fixed wing focus is anti-air warfare and theater missile defense- with ranges beyond 500 km.

3.2.3.2.4 Multi-Wavelength Multi-Function Lasers. DTO SE.12.02.ANF. This effort will develop laser sources and systems for multi-function applications. The approach is to utilize a single laser source embedded in a system to accomplish multiple functions (e.g., rangefinding, designation, identification) thus enhancing affordability and platform size capability. Multi-wavelength output of .26-5 microns will be demonstrated allowing eyesafe operating modes for more robust training and to minimize personnel injury. Investigate Horizontal Technology Integration approach across multiple system platforms.

3.2.3.2.5 Aircraft Signature Measurement/Modeling Technology. DTO SE.13.03.NF. This effort will predict IR signatures of aircraft and integrate them into engagement models and specifications resulting in a better assessment of aircraft vulnerability and weapon systems delivery. Flight test hours for signature acquisition will be reduced by 50% from Convention & Data Acquisition Procedures.

3.2.3.3 Basic Research. Basic research capitalized on in this area includes III-V and II-VI material growth by MBE for IR detectors, OMCVD material growth for laser diode sources, image and signal processing algorithms, and non-linear optical materials. Future required research includes multi-spectral smart FPAs, multi-sensor fusion algorithms, mid-wave laser diode sources and high bandwidth optical processing techniques.

3.3 Acoustic Sensors

3.3.1 Warfighter Needs

Joint warfighting operational needs/capabilities in the areas of dominant battlespace knowledge, combat identification, joint readiness, and joint countermine are particularly dependent on acoustic, magnetic, and seismic sensor technology. These sensors provide reliable undersea and terrestrial surveillance against threat targets which is required to achieve and maintain battlespace dominance to enable timely execution of joint/combined operations in support of national security objectives. Undersea acoustic sensor efforts are Navy unique and Navy critical.

This Subarea develops surveillance and environmental science & technologies to acoustically and magnetically detect, classify, track and localize quiet threat targets in all

operating environments across all missions and all platforms. Acoustic sensors are the primary sensor of choice to detect threat submarines operating below periscope depth. However, the increasingly quieter nuclear threat and the diesel-electric-on-battery threat limits traditional narrow-band processing, yielding shorter detection ranges and requires more array gain via more sensors and adaptive signal processing to counter the quieting trends. Acoustic sensors are highly dependent on environmental conditions so the shift in focus to the littorals presents a more difficult environment which is more familiar to the enemy and leads to increased clutter from biologics and other sources resulting in higher false alarm rates and greater weapon expenditures. To counter the environmental issues fusion of acoustic sensors with magnetic and other nonacoustic sensors are finding increased use. Effective multi-sensor data fusion offers more robust detection and classification performance and offers a greater range of adaptability. Larger array apertures requires emphasis on affordability if such systems are ever to be fielded. Navy applications include undersea surveillance in both open ocean and in highly variable, cluttered, shallow water areas by hull mounted, towed and deployed systems from surface ship, submarine, fixed-wing and helicopter platforms, while Army applications include shore area and battlefield surveillance to detect and classify ground and air targets with mobile and stationary sensor systems from fixed and mobile platforms as well as for short range mines.

3.3.2 Acoustic Sensors Overview

3.3.2.1 Goals and Timeframes. The worldwide proliferation of modern quiet diesel-electric submarines requires increased emphasis on the use of active sonar and full spectrum passive processing. Improved classification for existing active sonar systems is the short-term (<5 years) goal. Within 10 years, high gain passive systems and active sonar systems that can adapt to the highly variable littoral environment and accurately classify targets in high clutter environments with reduced false alarm rates are required. Modern Army battlefield acoustic systems have demonstrated the capability to detect, classify, and identify ground targets at ranges in excess of 1 kilometer and helicopters beyond 5 kilometers with meter-sized sensor arrays while netted arrays of sensors have been used to track and locate battalion sized armor movements over tens of square kilometers in non-line-of-sight conditions.

Far-term improvements will extend these capabilities to tactical ranges. Significant goals are:

FY98	Demonstrate optical array technology providing 5x decrease in acquisition costs with higher bandwidths and dynamic ranges Transition signal processing algorithms to the surface ship SQQ-89 sonar system improving active classification Test 100x wider frequency band magnetic sensors Demonstrate ability to track large vehicle formations with real time tracking and identification
FY00	Demonstrate 5x increase in active source bandwidth Demonstrate battery powered deployed active source Test environmentally adaptable volumetric passive arrays which can provide near real-time aperture flexibility
FY01	Test the LBVDS

FY05	Demonstrate optical array technology providing a further 2x reduction (overall 10x relative to FY95) in towed array acquisition costs and providing programmable apertures Demonstrate data linked autonomous distributed deployed sensor systems Demonstrate 10x area coverage using integrated all sensor fusing

Advances to meeting these goals depends on progress in Electro-optics Technology (3.7), understanding the Ocean Battlespace Environment (3.12) and Acoustic and Magnetic Materials.

3.3.2.2 Major Technical Challenges. In general, the major technical challenges are to provide:

- Highly effective USW shallow water ASW that can adapt to the environment; include high resolution environmental modeling and measurement; and incorporate "through the sensor" environmental characterization;
- Low cost options for USW systems (affordability); and
- Improved tactical decision aids through near real-time simulation coupled with more capable sensing & modeling of the tactical environment.

Specifically, major technical challenges included: (1) active sonar detection techniques for targets in clutter caused by non-target geologic features, biologic, man-made objects on the bottom and reverberation from surface, bottom and volume interactions, (for example, CST-5 sea trial data show "routine" deep water performance hampered by 2 to 12 false tracks per hour and in shallow water, performance is impeded by over 300 false tracks per hour); (2) passive sonar - algorithms capable of detecting targets in the midst of interference from local and distant shipping and (3) active and passive sensors - compact, high power, lower and broader frequency active acoustic sources and larger aperture receiving arrays in affordable applications on a diverse range of platforms.

3.3.2.3 Related Federal and Private Sector Efforts. COTS plays a significant and growing role in this subarea. Telecommunication technology, fiber optics and associated laser, coupler and splitter technology, polyvinylidene fluoride (PVDF) materials and computationally intensive hardware are applicable examples.

3.3.3 S&T Investment Strategy

3.3.3.1 Technology Demonstrations. The LBVDS will combine advances in high energy density transduction materials and in broad frequency bandwidth waveform generation and signal processing in a 1 to 6 kHz sonar system to provide shallow water environment USW capability to Naval surface ship platforms. Real-time clutter rejection, reverberation suppression, target highlighting, and classification will be evaluated through sea tests of the broadband waveforms. A compact, towable source projector and receive array with manageable ship design and operational impact will be developed and used as the test bed. The LBVDS payoff will be an estimated greater than 20 dB improvement in detection and classification, more rapid localization, a false alarm goal of less than one per hour against quiet, slow submarines and mines in shallow water. The technology is targeted for transition to SC21.

3.3.3.1.1 Lightweight, Broadband Variable Depth Sonar (LBVDS). This demonstration addresses DTO SE.14.02.N.

3.3.3.2 Technology Development

3.3.3.2.1 Sensor Signal Processing Technology. This technology development addresses DTO SE.15.01.ANE. Efforts develop active waveform designs; improve signal processing and displays to reduce clutter and false alarm rates encountered in cluttered environments; investigate bi-static/multi-static detection technologies; provide algorithms and data fusion techniques which increase probability of detection with reduced false alarms; demonstrate long range, ground and air target direction and identification at low cost. The signal processing approach is to develop algorithms and architectures to enable autonomous detection and classification, enabling reduced operator loading/manning. Target separation is addressed by improving on array bearing accuracy and beamforming. Fusion of multiple sensor modalities in a hierarchical neural net will be used to achieve a high probability of detection with a low false alert rate. Other techniques include passive processing utilizing the complete spectrum of target emitted signals, platform noise suppression, and wind noise reduction. A shallow water data base of target and non-target echoes in high cluttered environments will be collected to use in developing and demonstrating signal processing techniques to reduce clutter and improve classification.

3.3.3.2.2 Active/Passive Sensor Technology. This technology development addresses DTO SE.16.01.NE. Active efforts will develop innovative, high power transducers using new, high energy density transduction materials, e.g., the electrostrictive lead magnesium niobate (PMN) and the magnetostrictive Terfenol-D. Array element interactions will be modeled to aid in providing affordable, compact sources with minimal ship impact that can be towed at the optimum depth determined by the environmental conditions and the target's depth. Deployed or offboard sensors and distributed systems are needed to provide alerts and cueing to tactical platforms. Efforts include the development of affordable, lightweight, extended bandwidth optical sensors, velocity sensors, micromachined sensors, and rugged soldier mounted acoustic sensors for long-range and early warning threat detection. Sensor noise models and noise mechanism insights are required to optimize aperture designs.

3.3.3.3 Basic Research. This Subarea is interdisciplinary in nature, drawing on efforts in materials, mathematical, computer, information, cognitive, neural, surveillance and battlespace environmental sciences. Environmental effects play a major role in sensor performance and insight of the complexities offers a means to develop adaptable systems.

3.4 Automatic Target Recognition (ATR)

3.4.1 Warfighting Needs

ATR addresses the Joint Warfighter Operational Needs S&T areas as follows: (1) Dominant Battlefield Awareness - ATR gives real-time identification of adversary from high bandwidth sensors providing both sufficient knowledge to neutralize and, also, enormous data compression for transmission on battlefield data links; (2) Precision Force - ATR's real-time ID of forces over wide area compresses C4I timeline for responsive

“sensor to shooter” operations and enables timely reacquisition of target for strike platform; (3) Combat Identification - ATR gives beyond visual range ID to launch missiles at long range enabling lethal enemy engagement, reduced fratricide and ownship survival; (4) Joint Theater Missile Defense - ATR enables finding ground-based missile launchers in a timely manner consistent with clusive adversary operations, discriminating RV’s from decoys during reentry, and to discriminate cruise missiles from slow moving, low flying confusers; (5) Military Operations in Urban Terrain - ATR enables finding targets in cluttered urban environment to precisely ID targets allowing precision weapon employment resulting in minimal collateral damage; (6) Joint Readiness - ATR synthetic scene generation and modeling provides capabilities for enhanced simulation and training; (7) Joint Countermine - ATR technology enables rapid detection of mines; (8) Counterproliferation - ATR aids in timely bomb damage assessment. ATR is needed for both ISR and Weapon Delivery systems. Transitions planned for Joint STARS, P3, S3, U2R, Tier 2. Tier 2+, Tier3-, F14, F15, F16, F18, F22, Apache, Comanche, AWACS, Abrams, Bradley, MSX, THAAD Destroyer, CG-47, DDG-51, DDG-993, and DD-963.

3.4.2 ATR Overview

3.4.2.1 Goals and Timeframes. The ATR program goals are grouped into two categories—those organized by target class (land, sea, air), driven by the need to improve ATR performance and those that are general ATR goals driven by the need to reduce both acquisition and life cycle costs.

FY00	Ground Target Attack—Open Targets/Standard Configurations; 60x Search Area
	Ground Target Surveillance—Partially Obscured Targets; 150x Search Area
	Airborne Targets—35 Target Classes
	Surface Targets—Small Craft; 20 Classes
	Reentry Vehicles—Discriminate Crude Decoys
FY05	Ground Target Attack—Partially Obscured Targets
	Ground Target Surveillance—Multiple Tgt Configurations; 1000x Search Area
	Airborne Targets—100 Target Classes
	Surface Targets—Small Craft; 100 Classes
	Reentry Vehicles—Discriminate Sophisticated Decoys

Technological advances in this subarea are critical to attainment of identification goals in Radar technology (3.1) and Electro-Optic Technology (3.2).

3.4.2.2 Major Technical Challenges. The major technical challenge is the development of robust algorithms (single and multi-sensor) to contend with the target signature variations due to target configuration (e.g., stores, articulation, manufacturing, wear/tear), target/sensor acquisition parameters (e.g., aspect, depression, squint angles), target phenomenology (e.g., cavity responses, glints, IR thermal behavior), and target/clutter interaction (e.g., foliage masking, camouflage). These algorithms must also maintain low false alarm rates and operate in real time. Other significant challenges include rapid target insertion/on-the-fly training to support flexible and sustained

employment of ATR and the development of open architecture ATR's to provide expandable hardware and software insertion for affordable capability growth.

3.4.2.3 Related Federal and Private Sector Efforts. Image processing technologies are developed in medical imaging, law enforcement, automated manufacturing, transportation sensing, remote sensing, environmental sensing, robotics, and multi-media. Commercial computer technologies are leveraged as well.

3.4.3 S&T Investment Strategy

In addition to DTAP planning process and TARA reviews, the ATR community (government, industry, & university) meets 3 times a year at the ATR Working Group (ATRWG) meetings to promote industry involvement in planning and MOU coordination process.

3.4.3.1 Technology Demonstrations. Technology Demonstrations in this subarea contribute to several EO and Radar application DTOs which are demonstrating combined advances in sensor and ATR technology.

3.4.3.1.1 ATR Dominant Target ID. DTO SE.17.02.ANFEC. Demonstrations include both passive and active detection, tracking cueing and identification of targets in the battlespace. The following programs perform intelligent data compression and/or recognition of stationary ground vehicular targets from recce type platforms such as U2R or Tier 3-: SAIP, Clipping Service, STARLOS, and RADIUS. Efforts recognizing ground or air moving targets include Moving Target Recognition for Recce, Surveillance, and Attack; Air Target Algorithm Development; Non-cooperative Air Target Recognition; and Multi-sensor Fusion for Airborne Surveillance, and Moving Target Exploitation. Important transition targets include JointSTARS, P3, and S3 for ground and surface targets; and F14, F15, F16, F18, F22, and AWACS for airborne targets. Key developments performing multi-sensor recognition include Unmanned Ground Vehicle/Reconnaissance, Surveillance, and Target Acquisition Demonstrations, Hunter Sensor Suite (in RFPI ACTD), and Target Acquisition ATD (reported in EO subarea). Other activities include reentry vehicle discrimination from decoy's using EO and Radar sensors and Automatic Radar Periscope Detections and Discrimination using high range resolution radar.

3.4.3.2 Technology Development. Technology being developed in this subarea includes:

Development of both template and model based algorithms using single and multiple radar and EO sensors, attacking both ground and air targets.

Leveraging of commercially developed multi-chip modules to design and demonstrate a family of affordable, miniaturized, high density, high performance image and digital signal processors for advance weapons applications. ATR evaluation and databases are the backbone of ATR development as it is largely an experimental science, joint development of standard metrics, evaluation procedures, and databases and sharing under ATRWG pursued. Signature modeling and scene synthesis, critical to rapid target insertion capability and cost effective complement to training and evaluation field data is conducted.

Algorithm tools are developed, focused on a common environment to reduce ATR development and evaluation cost and improve algorithm performance via shared

and distributed algorithm design, software reuse, and de-coupling of software development from real time HPC architectures.

3.4.3.3 Basic Research. As outlined in the Basic Research TAP, ATR is a key focus for the 6.1 community. Important research themes include multi-resolution processing, fusion, advanced and non-linear signal processing, computational electromagnetics, algebraic invariance, artificial intelligence and knowledge based systems, advanced imaging techniques and inverse problems, and distributed/parallel computing. Recent key initiatives include the Reduced Signature Target Recognition effort which is focused on advanced algorithm and computational electromagnetic research and the Signal Processing and AI Program.

3.5 Integrated Platform Electronics

3.5.1 Warfighter Needs

In order for the warfighter to utilize the capabilities provided by sensors, decision aids, weapons, etc., they must be integrated in a manner such that the warfighter can understand his/her situational awareness, the mission plan and contingencies and such that their systems can be physically and functionally integrated on-board space, airborne, ship, ground and human platforms. The integrated platform electronics (IPE) subarea develops the technologies and tools to accomplish this including: electronic system architecture (fault tolerance, standards and interfaces, interconnects, modeling and simulation); resource and information technology (shared resource management); and electronic packaging (power management, cooling, modularity). As the cost of electronic subsystems approach 40% of the total acquisition cost of the entire weapon system, and account for virtually 100% of the mission capability of the weapon system, it is apparent that increases in electronic subsystem performance and reductions in cost will produce large impacts on weapon system cost and capability. As such, joint Warfighter Science and Technology being supported primarily include: dominant battlespace environment, precision force, combat identification, joint theater missile defense, electronic warfare and information warfare.

These technologies have transition potential to a wide variety of military aerospace systems, i.e., F-15/F-16/F-18/F-117, AH-64 upgrades and retrofits for service life extension; RAH-66/V-22/

F-22 growth; F-18/F-22 derivatives; and the JAST new strike fighter developments. The technology developed under this effort can be utilized on commercial and civilian aircraft, ships, automobiles and space craft. The latest commercial aircraft are moving toward greater levels of integration and military use of commercial technology, tools and standards will enhance transition opportunities.

3.5.2 Integrated Platform Electronics Overview

3.5.2.1 Goals and Timeframes

FY98	Structurally embedded antenna array on F-18 providing a 20-40% weight reduction 20-50% reduction in acquisition cost
FY98	Integrated Sensor System for strike aircraft with 50% weight and volume reduction, 30% acquisition and support cost, and 300% improvement in reliability
FY00	Avionics system (both new and upgrade) development, procurement and support costs reduced by 30%, avionics system development time reduced by 25%, avionics prime power requirements reduced 30%, avionics system reliability increased by 200%
FY05	Avionics system (both new and upgrade) development, procurement and support costs reduced by 50%, avionics system development time reduced by 50$, avionics prime power requirements reduced 50%, avionics system reliability increased 400%.

The efforts in this area draw heavily on the output of the technology developed in Radar (3.1), Electro-Optic Sensors (3.2), Microelectronics (3.8) and Electronics Integration Technology (3.10), as well as, from other DTAPs involving communications and electronic warfare.

3.5.2.2 Major Technical Challenges. In order to reduce the electronic system cost and weight by a factor of two and to improve system reliability by a factor of three, significantly new approaches are needed for the system hardware and software. Some of the key issues include: wide bandwidth, high dynamic range sensor components which can be time-shared to support multiple functions; low cost commercial-off-the-shelf hardware and software components which can be packaged to survive the severe environment of military applications and will support real-time tasking and performance monitoring; development of reliable super-high density connectors and fiber optic components to implement high bandwidth bus structures; packaging approaches which can accommodate high thermal densities associated with VHSIC and Monolithic Microwave Integrated Circuits (MMIC) components. The major advances required are in the areas of multi-level secure data manipulation, system level sensor management and fusion, increased situation awareness, and improved crew productivity with reduced crew size.

3.5.2.3 Related Federal and Private Sector Efforts. There is an enormous amount of research in the electronics industry which is applicable to military systems. The major challenge to military use of the technologies is in the packaging and adapting of these technologies to the very difficult performance requirements and severe operating environment found on military weapon systems. Electronics research at NASA is primarily focused on flight control systems with more modest performance requirements than mission electronics and significantly greater reliability requirements which derive from flight safety considerations.

3.5.3 S&T Investment Strategy

3.5.3.1 Technology Demonstrations

3.5.3.1.1 Integrated Platform Avionics Demonstration. This demonstration addresses DTO SE.18.01.NFE and will demonstrate how technology developments in integrated EO and RF sensors, avionics architecture, signal and data processing, and resource/information can affordably extend the useful life of tactical strike aircraft. This demonstration, as well as the avionics demonstrations being accomplished under the JAST program, will serve to validate the cost and weight reductions being sought. This demonstration will occur in this FY 2000-2002 timeframe and will support affordable avionics upgrades for JAST variants, F-22 and current operational aircraft upgrades (F-15/16/18/117, CH47, AH-64).

3.5.3.2 Technology Development. In order to truly achieve "integrated electronics" on military platforms, a number of disparate technologies must functionally inter-operate to produce an optimized weapon system. These constituent technologies include: electronic system architecture (fault tolerance, standards and interfaces, interconnects, modeling and simulation); resource and information technology (shared resource management, multi-sensor integration, multi-source fusion, automated decision aids); electronics packaging (power management, cooling, modularity); electronics processors and data storage (memory, processors, archival storage, software, machine intelligence).

3.5.3.3 Basic Research. Advances in this subarea require research across a broad spectrum of sciences including electronic materials and packaging, expert system, artificial intelligence, systems theory, sensor fusion, etc.

3.6 RF Components

3.6.1 Warfighter Needs

Radar remains DoD's primary all-weather sensor to provide capabilities such as surveillance, situation awareness, self and area defense, targeting, and battle damage assessment. In addition, a major compliment to the hardkill capability or weapons is the softkill afforded by EW systems which can potentially handle a much larger attack force than hardkill weapons. Finally, the glue that holds all these capabilities together to form an effective warfighting force is the communications networks. These three areas rely heavily on and are enabled by RF technology which represents the key to force multiplication (the ability of a minimum number of U.S. platforms and personnel to defeat a much larger enemy force), and the avoidance of technological surprise on the battlefield. The following Joint War Fighter S&T areas are supported: Dominant Battlespace Knowledge, Information Warfare, Precision Force, Combat Identification, Electronic Warfare, Joint Theater Missile Defense, Military Operations in Urban Terrain, Joint Countermine, and Joint Readiness. The availability of affordable, manufacturable RF electronic components which satisfy the performance, weight, size, interoperability, cooling, and maintainability requirements of military systems is vital for sustaining the competitive edge of U.S. forces over their adversaries. These warfighting capabilities require reductions in size, weight, volume, power consumption and costs. Advanced high performance and affordable RF MMIC technology is currently being transitioned

into a broad range of military systems, including the F-15/ALQ-135, LANTIRN, AMRAAM, MILSTAR, GEN-X, GBR, LONGBOW, SADARM, STAFF, and F-22 radar and EW arrays.

3.6.2 RF Components Overview

3.6.2.1 Goals and Timeframes. The RF Components thrust involves the technology required to generate, control, radiate, receive and process VHF, UHF, microwave, and millimeter wave power. The technologies under development are applicable to: solid state and vacuum electronic devices, low noise and signal control components, microwave power modules (MPMs), monolithic microwave integrated circuits (MMICs), transmit/receive (T/R) modules, advanced packaging and interconnect technology, antennas, and frequency control devices. The four technology efforts that comprise the RF Component Subarea are Solid State, Vacuum Electronics, Antenna Support, and Frequency Control. The results of these efforts enable many of the goals in Radar (3.1), Communications and Electronic Warfare.

FY97	>20Watts & >40% efficiency solid state HBT power amplifier for SHF SATCOM Development of affordable, very compact, transmitters generating 100 to 250 watts below 18 GHz and 50 watts in the 18-40 GHz range for EW, radar, & communications systems Demonstration of wide bandgap semiconductor & devices for high power/high temperature RF sensor transmitters Achievement of 100x reduction in frequency control oscillator acceleration sensitivity
FY98	Produce affordable higher power, higher efficiency microwave & millimeter wave (e.g., 8-10 GHz multi-chip assemblies with >10 watts output power and 30% efficiency) transmitters, and lower noise figure, high gain receivers, packaged in thin, lightweight, high density packages for airborne and spaced-based phased array antennas
FY00	Achievement of first efficient full digital beamforming capability on transmit and receive Ability to produce millimeter wave (35-140 GHz) circuits and subsystems with electrical characteristics suitable for use in smart weapons, all-weather multispectral vision systems and identification friend-or-foe systems with costs low enough to allow affordable field insertion
FY02	Development of advanced RF control technology, including RF, optical and digital components for fully integrated, multi-function radar, EW, & communications sensors
FY03	Use of piezoelectric resonators for lightweight chemical and biological agents detection

3.6.2.2 Major Technical Challenges. A particularly challenging technical obstacle confronting military systems is that of producing affordable solid state amplifiers for broadband microwave and millimeter wave applications that simultaneously achieve high output power, high efficiency, small volume and acceptable

linearity. Specifically, amplifiers meeting these objectives must be produced that have instantaneous bandwidths extending over frequency ranges from 1 to 18 GHz, 18 to 40 GHz, 40 to 75 GHz, 75 to 110 GHz, and 110 to 140 GHz, at costs ranging from one-fifth to one-tenth that which can be achieved using present design approaches and manufacturing capabilities. The following projects are being undertaken in order to address these deficiencies: (1) intensive effort is continuing at the inter-chip level to develop improved, more compact packaging and interconnect technology, and at the intra-chip level to increase the level of IC integration; (2) in the frequency control sub-area, a project has been planned to achieve a 100x reduction in oscillator acceleration sensitivity; (3) to achieve greater (10x) clock accuracy with lower power requirements, new (quartz-like) piezoelectric materials, such as langasite and lithium tetraborate, and novel resonator structures are being explored; and (4) to realize multiple-function, reconfigurable antenna arrays, work is in progress to identify and realize viable approaches for reconfiguring apertures so that they can perform multiple functions and provide failure correction.

3.6.2.3 Related Federal and Private Sector Efforts. Related efforts include metrology work with DOC/NIST and joint programs with NASA in solid state and vacuum electronics.

3.6.3 S&T Investment Strategy

3.6.3.1 Technology Demonstrations. None

3.6.3.2 Technology Development. Particular emphasis is being placed upon the development of Integrated CAD (Solid State and Vacuum Electronics); High Density Packaging; Wideband, High Power, Highly Efficient Vacuum Tube and Solid State Amplifiers; Mixed Signal ICs; Materials for Frequency Control; MMW Integrated Circuits; and Compact Multifunction Antennas.

3.6.3.2.1 Compact High Power RF Transmitters. This development addresses DTO SE.19.01.NF. The main objective is the Microwave Power Module (MPM) technology development and to facilitate the transition and insertion of MPMs into a wide range of radar, electronic warfare and military communications systems. Specifically, the effort seeks to demonstrate: single-device and linear (1xn) arrays of 6-18 GHz, 50-to-100-watt MPMs for EW transmitters; 250 watt, 8-18 GHz MPMs for standoff jammer systems in which multiple threat signals are simultaneously processed; 125 watt, 4-6 GHz MPMs for communications applications with efficiencies greater than 40%; and 50 watt, 18-40 GHz MPMs for EW, radar, and communications applications.

3.6.3.2.2 Affordable Multi-Chip Modules for Phased Array Antennas. The DTO SE.20.01.FE seeks to develop high density microwave and millimeter wave packaging and interconnect technologies for shallow depth/conformal phased array antennas used in radar, EW, Smart Weapons and communications technology. Goals include: 5:1 volume reduction; 10:1 cost reduction; and 2.1:1 weight reduction.

3.6.3.2.3 Low Power Consumption RF Electronics. DTO SE.21.01.FE is developing affordable, low power consumption RF electronics for military man-portable communications and for airborne/space platforms that are volume and weight starved. This effort addresses the full spectrum of components and devices for these applications.

3.6.3.3 Basic Research. Basic research in the RF Component technology area is directed toward the synthesis of advanced semiconductor, superconductor, and ferrite materials, and the development of affordable processing sequences for them. The successful completion of research tasks in these areas will enable development of high performance, reliable, low-cost structures for RF devices and components used in DoD systems. Basic research efforts provide technology options for device and component designers and fabricators that may lead to the realization of improved or entirely new classes of devices and components. Specific device/component-related goals that motivate these efforts are: achievement of improved device performance (e.g., higher frequency, higher temperature operation, high efficiency, lower noise, reduced complexity, and ability to support small feature sizes), lower cost, higher yield, improved predictability of properties, and greater reliability.

3.7 Electro-Optics Technology

3.7.1 Warfighter Needs

Detection, precision location and tracking; specific identification; and accurate battle damage assessment are key to the Joint Warfighting S&T areas or dominant battlespace knowledge, precision force, combat identification, joint theater missile defense, military operations in urban terrain, electronic warfare and counter proliferation. Electro-optics provides better target resolution than radar and, due to its narrow beam, provides better target location. Both are key issues for the aforementioned JW S&T program areas. In addition, the increased EO/IR threat requires active EO/IR systems for target EO/IR countermeasures. In short, advances in electro-optical (EO) device technology are required in photonics, displays, lasers and focal plane arrays (FPAs). The continued development of high performance human-in-the-loop and autonomous systems will significantly advance global surveillance and communications capabilities; all-weather, day-and-night, camouflage-resistant precision strike missions against fixed and mobile targets; more effective electro-optic countermeasures; advanced antisubmarine warfare capability; and increasingly potent space laser radar and sea control systems.

3.7.2 Electro-Optics Overview

3.7.2.1 Goals and Timeframes. In order to meet future Warfighter goals, improved sensors and sensor data processing will be needed. This will require investment in enhanced processing and manufacturing technologies that will result in better and more affordable EO devices. For example, work will continue on advancing OMCVD (Organo-Metallic Chemical Vapor Deposition) processing techniques, which have already yielded 3x-5x improvements in laser diode efficiency as well as a 100x reduction in the cost/watt of such diodes. Similar cost reductions have been achieved for FPAs (relative to early prototypes) coupled with more than an order of magnitude improvement in performance compared to that of scanned linear IR detector arrays, the presently deployed technology. The results of this subarea enable many of the goals in the Electro-Optic Sensors (3.2), ATR (3.3) and Communications/Data Links.

Specific goals include:

FY96	Demonstration of 16 element fiber optic feed for 10 GHz phased array.
FY97	Spectrally discriminating MWIR FPA. Flexible manufacturing of HgCdTe FPAs in burst mode. Demonstration of wavelength division multiplexed system with capacity >100 GB/s.
FY98	Smart IRFPA with biologically inspired processing on chip.
FY99	94 GHz analog links with less than 50 dB loss over kilometers of fiber. Total optical control of phased array radar using fiber optics. Ultraviolet imaging array.
FY00	Multicolor IRFPA with on chip processing. Full color 2000x2000 element helmet mounted displays.

Long-term (2001-2005) goals include: integration of IRFPA and ATR functions in a 1-inch cube (to enable true fire-and-forget autonomously targeted missiles and bombs) and 3-D stereoscopic displays and parallax-free heads-up displays.

3.7.2.2 Major Technical Challenges. Key technical challenges in the laser and IRFPA areas include increased diode laser array wavelength availability in the MWIR and LWIR bands; reduced size, weight and power consumption of laser systems; and reduced cost of laser diode arrays to $1 per peak watt. Another challenge is producing multi-spectral FPAs, in the long term, for detecting dim and camouflaged targets, particularly in background clutter. Effort will be focused on dual-band IRFPAs (MWIR and LWIR, as well as different parts of a single band). In the near term, smart FPAs with on-chip electronics, improved signal and image processing, automated targeting functions and reduced acquisition timelines can be developed. If cost effective, stereoscopic/3-D displays can be developed, they would enable new capabilities in command and control and in situation awareness.

3.7.2.3 Related Federal and Private Sector Efforts. There are significant efforts in industry in flat panel displays, fiber optic cables and optical components. For example, Bell Laboratories is a major player in photonics and fiber optics. These efforts must be leveraged with DoD funding advancing those areas where industry products will not meet DoD requirements or not meet them in the required timeframe.

3.7.3 S&T Investment Strategy

3.7.3.1 Technology Demonstrations. Some core demonstrations include IRFPA flexible manufacturing program to enable the manufacture of multiple application-specific IRFPAs at low cost even for low volume, fast-turnaround requirements and the ARPA BIT program which is developing key enabling technologies for terabit optical fiber networks with global reach.

3.7.3.2 Technology Development

3.7.3.2.1 Advanced Infrared Focal Plane Arrays. This program is (DTO SE.22.01.ANFE) developing FPAs with selectable/simultaneous spectral regions to increase reliable detection ranges and decrease false alarm rates. Manufacturing technology for ensuring low cost and ultimate performance flexibility in responsivity, waveband selection and automated functions will be emphasized. Detection of objects in space requires arrays optimized for longer wavelengths (12-30 mm) which may operate at lower temperatures.

3.7.3.2.2 Militarized Flat Panel Displays Technology. This technology development addresses DTO SE.23.01.E and will develop miniature high resolution (up to 2K by 2K pixels) display subsystems to provide head mounted displays for use with ground or air mobility sensors, rotary and fixed wing applications, and complex system displays used for future maintenance manuals and for UAV sensors. It will leverage the ARPA miniature flat panel effort and consist of advanced, lightweight optics capable of providing up to a 60^{o} field of view at high resolution and with low power analog-driven stereoscopic displays.

3.7.3.2.3 Optical Control of Radar, Communication, and Electronic Warfare Systems. This technology development addresses DTO SE.24.01.NF and also several DTOs and Weapons (Electronic Warfare) DTAPs. The major capabilities and deliverables are optical control of phased array antennas and optical beamforming networks; components for 100 Gbit/s wavelength division multiplexed all-optical networks; guided-wave, high-speed (>40 GHz) electro-optic modulators; multi-element, true-time-delay optical beamformers.

3.7.2.4 Advanced Optics and Display Applications. This program (DTO SE.31.01.A) is identifying and, where, necessary, developing sensors and display technologies which can be integrated into high performance, light-weight, head-mounted vision systems. Such a capability will provide the soldier with a significantly improved battlefield awareness. Future opportunities include cross platform application of this same technology to armor and aviation.

3.7.3.3 Basic Research. Key basic research areas that can enable electro-optics technology include optical materials growth; new concepts for efficient, wavelength flexible, solid state lasers; and detectors.

3.8 Microelectronics

3.8.1 Warfighter Needs

The warfighter has become critically dependent on the ability of systems to collect and process information and thereby effect force multiplication through remote and distributed awareness and control. Technology for sensing, processing and computing information from the battlespace is strongly dependent upon microelectronics technology; hence this technology strongly supports the areas of Dominant Battlespace Environments, Information Warfare, Precision Force, Combat Identification, Electronics Warfare, and Joint Theater Missile Defense, along with significant support of Counterproliferation, Chemical and Biological Warfare Detection, Joint Countermine, and Joint Readiness. Key military equipment to achieve these capabilities, such as sensor packages, satellites, and man-portable communication equipment, need to meet stringent

military requirements (e.g., radiation and high temperature environments, extended operating lives, lower weight, and high performance) in order achieve these capabilities in the range of potential environments and situations. Another crucial factor affecting DoD's ability to provide superior capabilities to the warfighter is the cost of electronic systems, which depends directly on the producibility, quality, and cost of microelectronic devices, circuits, and fabrication technologies. Over the short term (1-2 years), electronic systems enabled by microelectronics should double the capability for processing information in the battlespace, while reducing cost, power consumption and weight by a factor of two. In the midterm (3-5 years), it is expected that microelectronics will enable a doubling of sensing resolution, range and/or speed; reduce power consumption by a factor of 10; and reduce weight by a factor of 10. In the long term, microelectronics innovations should enable an order of magnitude improvement in the range of sensing capabilities, while decreasing cost, power consumption and weight by more than a factor of 100. The technologies for signal conversion and processing, low-power, radiation resistant microelectronics, and microelectromechanical systems (MEMS) all have the potential to significantly increase the capabilities of weapon platforms and information systems, while simultaneously decreasing their size, weight, cost and assembly complexity. The dramatic rate of microelectronics technology innovation has also created the need to ensure that the warfighter has access to current state-of-the-art microelectronics in order to sustain superiority. Toward that end, the rapid transition of new technology to the industrial base and insertion of new (possibly commercial) technologies into military systems will continue to play an increasingly important role in meeting future warfighter needs.

3.8.2 Microelectronics Overview

The Microelectronics technology subarea makes use of electronic materials technologies (e.g., silicon and its compounds, gallium arsenide and other III-V compounds) to support a number of key DoD applications, including digital-to-analog and analog-to-digital converters (DACs and ADCs); direct digital synthesizer (DDS) devices; high temperature and high power silicon carbide (SiC) devices and circuits; radiation-hardened devices and circuits; and MEMS.

3.8.2.1 Goals and Timeframes. The Microelectronics subarea develops device, circuit, and fabrication technologies to realize digital, analog, and mixed-signal integrated circuits that are needed for introduction in a timely and planned fashion into weapons systems to ensure superiority over our adversaries. Specific goals include:

FY96	Development of integration techniques for MEMS-based microscale sensors to integrate thousands of transistors and 10-20 mechanical components on the same chip. Develop a MEMS-based integrated inertial guidance system on a chip.
FY97	Increase present levels of number of transistors to sensing/actuating elements in MEMS devices by two orders of magnitude.
FY98	Develop fabrication technology to produce submicron radiation resistant microelectronics. Develop high temperature microelectronics capable of withstanding 500°C.
FY01	Develop highly integrated nanometer-feature-size MEMS-based microsystems that integrate sensors, processing circuits, and I/O (actuators, displays), produced by affordable, flexible fabrication techniques. Develop multi-GHz, deep-submission radiation resistand microelectronic fabrication technology for microelectronic components. Develop devices and circuits consuming extremely low power (0.1 mW/gate-MHz) as a result of advanced power management techniques.

3.8.2.2 Major Technical Challenges. Military systems continuously require increased information processing capability, but state-of-the-art commercial IC processes and products are designed primarily to maximize profits, usually at the expense of characteristics such as high frequency, low power, ultra-miniaturization, and radiation or temperature tolerance. Specific challenges include: reducing circuit power by two orders of magnitude while simultaneously increasing performance; providing devices and circuits capable of reliable operation at very high temperature; developing affordable radiation-hardened VLSI device technology for low-to-moderate quantities of military memory devices and signal processors; achieving sensitivities and stabilities in MEMS accelerometers or gyroscopes that are required for inertial navigation on a chip (three to four orders of magnitude better than the best available today); and driving the development of MEMS technology to the densities of integrated electronics and mechanics needed to provide single-chip implementation of a full inertial navigation function.

3.8.2.3 Related Federal and Private Sector Efforts. Annual commercial semiconductor sales now exceed $100B and there are a number of technology development efforts (mostly oriented towards products in the very short term) in areas such as low power, increased speed and density, and more affordable manufacturing. Development of high performance conversion devices is being done by Analog Devices, GE, IBM and TI. There are MEMS activities at Lawrence Livermore National Laboratories and U.C. Berkeley.

3.8.3 S&T Investment Strategy

3.8.3.1 Technology Demonstrations. None

3.8.3.2 Technology Development. The Microelectronics investment is focused on a broad range of goals. In addition to the efforts focused on SE.25.01.NFE, High Performance Microelectronics for Signal Processing and Computing, and SE.27.01.E, Micro-electromechanical Systems, there are efforts aimed at increasing microelectronic

density by 4x and speed by 50% using 0.18 μm feature size processing (mask repair and mainstream process flows). A 0.13 μm lithography capability is being explored (electron-beam and x-ray) which will increase density by eightfold and double the speed of operation. The following microelectronics efforts are being pursued to meet the microelectronics defense technology objectives:

3.8.3.2.1 High Performance Microelectronics for Signal Processing and Computing. DTO SE.25.01.NFE. Novel silicon and III-V devices are being developed from materials such as SiGe, SiC, TFSOS, GaAs, and GaN. These novel devices will be used to achieve low power SOI circuits and high performance circuits and applications (e.g., high temperatures, high speed data and signal processing, high speed/low power ADCs and DACs).

3.8.3.2.2 Radiation Resistant Microelectronics. DTO SE.26.01.AFH. Fabrication capabilities are being developed to produce state-of-the-art radiation resistant microelectronics. Investment is focused on leveraging commercial advances in the fabrication of microelectronics to produce key military components with performance and density close to commercial devices, yet able to withstand the sever radiation environment of space and strategic applications.

3.8.3.2.3 Microelectromechanical Systems. DTO SE.27.01.E. Reliable, repeatable MEMS-specific fabrication techniques are being developed. These techniques will be fed into developing MEMS devices and circuits that integrate sensing, actuation, computation, communication and control components.

3.8.4 Basic Research

The DoD basic research (6.1) investment in microelectronics is concerned with developing novel processes, devices and circuits using innovative materials and physical mechanisms. Key materials effort aimed at developing high quality semiconductor materials has made substantial progress in providing critical, military-unique device technology. Work in the areas of quantum transport, nanoscale electronics, mesoscale devices, surface and interface physics, and superconductors continues to provide the technology depth that DoD needs to sustain superiority in applied microelectronics and, most importantly, minimize the likelihood that a foe will be able to discover and exploit some new approach to effect technological surprise and defeat our fielded capabilities.

3.9 Electronic Materials

3.9.1 Warfighter Needs

Warfighters are increasingly exploiting electronic systems to achieve not only force multiplication but also the performance edge that promotes battlefield dominance. Much of this edge results from advances in devices developed for military-specific needs, advances that often exploit new capabilities provided by Electronic Materials technologies. Both the performance and cost of radar, communications, information warfare, and other electronic systems depend directly on the reproducibility, quality, and cost of electronic materials synthesis and processing, as well as the ability to tailor materials characteristics. Advances in the Electronic Materials subarea transition into the RF Components, Electro-Optics, and Microelectronics subareas which, in turn, transition into the Sensors subareas and the ATR and Integrated Platform Electronics subareas, as

well as many outside the Sensor, Electronics, and Battlespace Environment DTAP. This subarea therefore strongly supports almost all of the Joint Warfighter Science and Technology (see Figure I.3). For example, advances in III-V semiconductor substrate and films have led to revolutionary new devices that will make more compact radars and higher frequency/data rate communication systems possible in the midterm (3-5 years). In the midterm and long term, materials for infrared focal plane arrays (IRFPAs) will make modules possible that will be capable of broader-band detection and multiple color response for enhanced surveillance and room temperature operation for high-sensitivity mobile night vision equipment; wide-bandgap semiconductors will make electronics available that operates at 300°-500°C (e.g., near engine components), as well as compact ultraviolet lasers for full-color displays, high density data storage for C^4I, and covert communications. Because advances in electronic materials technologies can frequently be integrated into civilian use, even though the civilian utilization alone could not support the necessary development, DoD programs will benefit the civilian technology base, whose enhanced capabilities can then be used to satisfy military applications.

3.9.2 Electronic Materials Overview

The Electronic Materials subarea is directed toward the creation of new materials and the improvement of existing materials intended for device applications. It is *not* aimed at tailoring capabilities of specific devices (e.g., by improving a particular device parameter). Device/component performance, reliability, and reduced cost are the benchmarks of success. This subarea encompasses chemical synthesis; bulk and thin film/nanostructure materials fabrication; development of materials fabrication processes; and electrical, optical, structural, morphological, and chemical characterization. Classes of interest include semiconductor, superconductor, ferro/ferrimagnetic, ferroelectric, and nonlinear optical (NLO) materials.

3.9.2.1 Goals and Timeframes. The Electronic Materials subarea develops materials, fabrication processes, and device structures that are not supported commercially; are necessary for developing RF, microelectronics, and electro-optical (EO) devices and components; and combine affordability and reliability with high performance for use in DoD systems. Some specific embodiments of these goals are:

FY98	Cubic SiC substrates and films for operation at 300°-500°C. Improved GaAs and InP substrates for RF, digital, and E-O devices with production costs reduced by up to 50%. High-Tc superconductor (HTS) films for millimeter wave radar and communications. Substrates for high quality films of Group III nitride (III-N) and II-VI semiconductors. (Efforts to improve these materials will continue past FY00)
FY99	III-V and SiGe semiconductor heterostructures tailored to RF, optoelectronic, and detector applications.
FY00	New processes and materials that enable fabrication of prototype opto-electronic, integrated circuits that marry the best performance qualities of electronics and opto-electronics.
FY05	New and novel nanostructures and fabrication processes for ultrahigh-speed optoelectronics.

3.9.2.2. Major Technical Challenges. Threads that link most Electronic Materials efforts are the need to reduce the concentration of deleterious defects; to control material composition (including judicious introduction of intentional impurities), structure, and morphology in order to tailor properties; and to develop fabrication and characterization methods that result in high quality materials at affordable prices. Additional challenges depend upon specific materials and the maturity of the technology. The near-term challenge for high temperature semiconductors and HTS materials, both of which are at early stages of development, is to produce material having properties suitable for demonstration devices and small-scale components. Substrates that match the lattice constants and thermal expansion coefficients of III-N films are especially needed. For the more nearly mature GaAs- and InP-based materials, challenges include fabrication of larger-diameter substrates having lower defect densities, higher uniformity, and lower cost; further controlling and exploiting the relationships among growth environments and resulting properties—particularly controlling heterostructure interfaces such as InGaAs/InP and minimizing the strain induced by lattice mismatches between constituents of the heterojunctions. Key technical challenges for IR detector materials are the achievement of greater uniformity, more precise process control, and, for heterostructure detectors, control of interfaces and strain.

3.9.2.3 Related Federal and Private Sector Efforts. In the US, AT&T, H-P, Texas Instruments, Raytheon, Lincoln Lab, Hughes, and several universities have important III-V epi programs. NIST works with AF-RL/ERX and AF-WL/ELD to characterize wafers manufactured by contractors in the Title III GaAs substrate program. M/A-COM, Litton Airtron, and AXT market GaAs substrates; Crystacomm and AXT produce InP substrates (however, none conducts significant internally funded R&D). H-P, APA Optics, ATMI, and some universities conduct important III-N work. Cree, Westinghouse, and NC State University fabricate SiC. NASA, NIST, LANL, Sandia, ANL, Lincoln Lab, AT&T, IBM, Westinghouse, Conductus, Superconductor Technologies, Dupont, and several universities have important HTS programs.

3.9.3 S&T Investment Strategy

3.9.3.1 Technology Demonstrations. Electronic Materials is primarily an enabling technology. Upon optimization of materials or processing technology, the technology is ordinarily transitioned to device development projects and to industry for scale-up or commercialization. Electronic materials are "demonstrated" by successful transitions into the device/component community.

3.9.3.2 Technology Development. By targeting high-leverage technologies, notably materials technologies that have diverse electronic and electro-optic applications, this subarea anticipates the needs of the DoD electron device and component communities. The work includes: [a] development of *nonlinear optical (NLO) materials* for mid-IR optical amplifiers and oscillators (e.g., for frequency-agile lasers for electronic countermeasures) and materials for optical computing/storage, target recognition, and optical interconnects; [b] *patterning and processing methods/materials/equipment* to make possible still higher packing densities for electronics, reducing weight and increasing functionality; [c] development and technology transfer of promising *process technologies* that will lower production costs and enhance device/component performance and quality; and [d] *HTS materials and*

structures whose near-zero RF electrical resistance can be exploited to create extraordinarily narrow-band filters and compact high-frequency, high-bandwidth antennas for jam-resistant, high-data-rate communications components. Additional efforts, summarized in the following subparagraphs, support DTOs.

3.9.3.2.1 Compact High Power RF Transmitters. DTO SE.19.01.NF. This DTO is supported by two areas of Electronic Materials R&D: Wide Bandgap Semiconductors, and Intermediate Bandgap III-V semiconductors. *Wide bandgap semiconductor* efforts focus on growing, cubic SiC substrates and on growing high quality (Al,Ga,In)N materials for high power RF and high temperature electronics. The III-N efforts include growth of lattice- and thermally-matched substrates (e.g., ZnO and $LiAlO_3$, plus high-risk-high-payoff efforts to grow GaN as a substrate). *Intermediate bandgap semiconductor* efforts include development of advanced InP substrates; III-V films, heterostructures, and nanostructures grown on GaAs and InP substrates by OMCVD and MBE; and SiGe heterostructures for RF heterojunction bipolar transistors (HBTs). GaAs-based materials development is being pursued because GaAs still dominates microwave electronics. InP-based materials (plus antimonides) are being developed for possible displacement of GaAs in high power and low noise microwave amplifiers.

3.9.3.2.2 Advanced Infrared Focal Plane Array. DTO SE.22.01.ANFE. This effort emphasizes infrared detector materials for applications that include IRFPAs for surveillance and night/adverse weather operations. Films and structures based on HqCdTe monolithic films with on-chip processing, on InAs/GaSb superlattices (capable of detecting wavelengths >12 μm) and on SiGe (for Schottky barrier devices) are being developed in pursuit of these goals.

3.9.3.2.3 Optical Control of Radar, Comm., and EW Systems. DTO SE.24.01.NFE; and Low Power Consumption Electronics DTO SE.21.01.FE. Intermediate bandgap III-V semiconductor efforts, described in para. 3.9.3.2.1, support these DTOs. Support for DTO SE.24.01.NFE derives from the fact that GaAs and InP are premier materials for high-speed light generation and detection, as well as for high-speed electronics. InP-based materials are the mainstay of optoelectronics for telecommunications, and thus are being developed for optically implemented control functions (e.g., of radar antenna remoting and true time delay control of phased array antennas) as well as for communications applications.

3.9.3.3 Basic Research. Electronic Materials technology opportunities are closely coupled to basic research. The latter creates the knowledge base undergirding the exploratory development efforts. This arose because Basic research provides the insight into material processes and properties which are exploited in the technology program. Most 6.2 efforts described above are organized so that 6.2 efforts have direct 6.1 counterparts and so they are synergistically intertwined.

3.10 Electronics Integration Technology

3.10.1 Warfighter Needs

Many of the Joint Warfighting S&T areas require significant advancements in affordable electronics technology, a major challenge given the relatively small volume of specialized military parts normally needed compared to commercial production volumes.

Miniaturized, power-efficient, reliable, high-performance circuitry is particularly needed for dominant battlespace knowledge, precision force, joint theater ballistic missile defense, and electronic warfare. Today, the cost, performance, size, weight, power consumption, testability, reliability and maintainability parameters of military systems all must be dealt with on an integrated basis.

3.10.2 Electronics Integration Technology Overview

The Electronics Integration Technology thrust is critical to all electronic equipment, affecting the performance, reliability, affordability and power generation, conditioning and distribution for virtually every type of system, both military and commercial. The thrust includes: (a) advanced design, test and quality assurance tools, methods, practices, standards and integrating environment aimed at enabling comprehensive synthesis and design from the individual transistor to assembled multiboard systems; (b) packaging, interconnect technologies and the supplier and manufacturing infrastructure which will preserve device performance throughout an electronic system while increasing reliability and reducing size, weight, volume and cost and; (c) advanced batteries, fuel cells, capacitors, Power Electronic Building Blocks (PEBBs), solar power converters, generators, and power management systems for manportable C^4I, Soldier Systems, land/air/underwater vehicle propulsion, tactical power systems, electric weapons and vehicles, emergency power, silent power generation, and smart munitions.

3.10.2.1 Goals and Timeframes. The DoD efforts in this area particularly address the long-term thrusts for maintaining the "technology edge"; reducing the size, weight and power; and improving the testability, affordability and quality of electronics. Major goals include:

FY97	Develop signal processing "virtual prototyping" capability and demonstrate 75% design time/cost reduction. Achieve one-month MCM design cycle with 80-90% recurring cost reduction. Increase primary battery energy by 40% using Li/MnO2.
FY00	GHz rate MCMs for affordable mixed analog/digital subsystems. High energy battery for Soldier System: 1/2 size battery for SOF. Digitally controlled vehicular power at 10% of the cost of current practice.
FY03	1-10 kw field power source: thin, conformal battery for Soldier System. Demonstrate full system CAE and integrate into scaleable manufacturing.

The impact of the thrusts in this area are pervasive through many of the technologies described in the DTAPs.

3.10.2.2 Major Technical Challenges. 100x-1000x faster and affordable "Virtual Prototyping" of electronic subsystems must be achieved, based on VHSIC Hardware Description Language (VHDL) reusable and interoperable model libraries and the development of analog, mixed-signal, and Microwave Hardware Description Language (MHDL) language capabilities. Low-cost environmental monitors, failure

analysis/prediction tools and techniques, built-in-self-test (BIST) techniques, and diagnostic evaluators are also key challenges. The next-generation of Multi-chip module (MCM) technologies must be developed for high speed, mixed-signal circuits to achieve data/signal processor miniaturization for the individual warfighter, satellites, autonomous vehicles, smart munitions and ATR processors. Rechargeable lithium-ion cell chemistries with energy densities greater than 100 Wh/kg may be alternatives for C4I training, tank starting and silent watch. Efficient electrode catalysts in fuel cells are key to 400 Wh/kg man-portable fuel cells for Soldier System microclimate cooling. New types of power electronic building blocks are essential to achieving a 10x improvement in vehicular power system affordability and performance.

3.10.2.3 Related Federal and Private Sector Efforts. Related design efforts include tool and computing environment standardization activities under the purview of the CAD Framework Initiative, a consortium of many of the key players in the Electronic Design Automation (EDA) and the Semiconductor Industry Association (SIA) communities. Related electronic module/subsystem and packaging efforts include MCM development at Sandia National Lab and consortium effort at the Microelectronics and Computer Technology Corporation, the Microelectronics Center of North Carolina, and the Semiconductor Research Corporation (SRC).

3.10.3 S&T Investment Strategy

The EIT Subarea is directed at the exploitation of modern electronics to provide a competitive battlefield edge. The technology efforts, developments and demonstrations are designed using a strategy that capitalizes on US industrial capabilities, with the overall objective of meeting present and future military system and subsystem cost and performance objectives. Because of the long life-cycle of military systems and reduced DoD budgets, EIT is concerned with both new and fielded systems.

3.10.3.1 Technology Demonstrations

3.10.3.1.1 Integrated Design Environment Technology. DTO SE.28.01.FE. A complex arithmetic unit for the UYS-2A Navy Standard Signal Processor, to be used in the Airborne Low Frequency Sonar (ALFS) helicopter is being developed. There are two "Model Year" demonstrations—one being a virtual prototype and the other, a hardware prototype. The RASSP design environments being used facilitates low-cost system upgrades and improved reliability, producibility, and supportability for embedded digital signal processors.

3.10.3.1.2 Electronic Module Packaging and Interconnect Technology. DTO SE.29.01.FE. This demonstration is aimed at reduction in packaging design and fabrication time and cost of application specific electronic modules. Under the Application Specific Electronics Modules (ASEM) Program, MCM technology efforts have been aimed at developing advanced MCM technologies to meet future DoD requirements not satisfied by current commercial printed circuit and hybrid circuit manufacturers; reducing nonrecurring engineering (NRE) cost and cycle time to $25K and one month, respectively, with first-pass success on designs; reducing the total recurring module costs for current technologies by an order of magnitude and providing DoD access to robust manufacturing capabilities.

3.10.3.1.3 Energy Storage and Distribution Technology. DTO SE.30.01.NFE. This effort is aimed at lightening the soldier's burden, increasing energy density and improving distribution efficiencies. This includes demonstration of superior, low-cost primary and rechargeable batteries and other silent portable power sources, as well as logistically acceptable sources of mobile tactical power such as generators, fuel cells, solar power converters and other advanced energy conversion devices. It will also demonstrate electronic power modules with 10x the power density of present devices at $1/10^{th}$ the cost for vehicles/weapons.

3.10.3.2 Technology Development. The technology efforts within the EIT Subarea are viewed as critical to the affordability and performance of all new and currently fielded electronic equipment. These efforts are concerned with breakthroughs in CAE methods and tools, quality assurance technology (including best-practice technology and processes, advanced electronic technologies, built-in-self-test (BIST), failure analysis/prediction tools and techniques and diagnostic evaluators); advanced MCM technology (including scaleable MCM foundries, known good die, CAD tools, test standards and procedures, mixed signal MCMs, testability, substrates, 3-D and optical interconnects, and prototyping); power storage and generation technology (including primary and rechargeable batteries, fuel cells, electrochemical capacitors, solar power converters, power devices, programmable building blocks, and HTS components); and distributed power technology (including high-efficiency power converters).

3.10.3.3 Basic Research. Computer aided engineering oriented research within the university community includes research ranging from individual "niche" tool development to unified environments for end-to-end electronic system development. Much research is currently being conducted in Digital Signal Processor (DSP) design systems, algorithms, architectures, and software systems. CAE tools for Low Power Electronic systems are in research and development. Research is also being conducted to provide very-high-energy density portable power sources. Technologies being researched include: Zinc-Air batteries and advanced hydrogen based fuel cell architectures using polymer-exchange membrane systems, and new hydrogen storage mechanisms.

3.11 Terrestrial Environments

3.11.1 Warfighter Needs

The Warfighter requires accurate terrain information and the ability to visualize such to optimize force movement and employment to successfully engage a potentially larger enemy force. Needs also include: weather-impact TDAs, combat equipment designed for possible terrain and climate, knowledge of impact or cold regions including logistics planning and doctrine, and the ability to identify nuclear weapons tests to improve the U.S. capability to monitor a Comprehensive Test Ban Treaty and support the DoD initiative in counterproliferation. The warfighter needs the types of capabilities listed to achieve superior knowledge of the battlefield through a common picture of the battlespace, win the information war and dominate maneuver during operations in all types of terrain.

3.11.2 Terrestrial Environments Overview

The Terrestrial Environment subarea emphasizes characterization and modeling of the physical phenomena, processes, interactions and effects associated with terrain, and its surface/subsurface features at scales of interest to ground combat forces.

3.11.2.1 Goals and Timeframes. The Terrestrial Environment goals and timeframes are shown below:

FY97	Demonstrate and transition to Army simulation centers a dynamic terrain visualization capability for obstacles to help create a virtual 3-D tactical environment to support training and mission planning during the Army's Task Force XXI exercise.
FY02	Automated generation/update of topographic data for mission rehearsal and terrain visualization.
FY07	Battlespace fly/walk-through and automated terrain analysis capability.

Understanding Terrestrial Environments is important to the design of Radars (3.1), Electro-Optic Sensors (3.2) and the planning of military missions.

3.11.2.2 Major Technical Challenges. A number of major technical challenges remain. These include:

- Understanding the coupling that occurs between the complex air, snow, frozen-ground, unfrozen-soil interfaces to predict acoustic energy propagation in winter.
- Reducing the time required to generate terrain and weather environments in distributed modeling and simulation.
- Identifying terrain features/targets automatically to respond within the enemy's decision cycle.
- Developing realistic models of the subsurface crustal structure and new methods of determining the depth and location of seismic events.
- Develop new techniques for discriminating seismic events, new and more efficient algorithms to process and analyze significantly larger data sets (all in real time) and a new capability to process hydroacoustic, radionuclide and electromagnetic information.
- Automated extraction and analysis of terrain features from all source remotely sensed data.

3.11.2.3 Related Federal and Private Sector Efforts. Other investment in this research is relatively low in cold regions and topography due to the focus on warfighting needs, although significant outsourcing does occur in seismology.

3.11.3 S&T Investment Strategy

3.11.3.1 Technology Demonstrations

3.11.3.1.1 Rapid Battlefield Visualization ACTD. DTO B02. Demonstrate capabilities to collect source data and generate high resolution digital terrain databases within the timelines required by the commander to support crisis support and force projection operations. The RBV ACTD will also demonstrate capabilities for the commander to manipulate and display terrain databases integrated with current situation data to: analyze courses of action; use embedded wargaming; and conduct mission rehearsals to visualize his desired end state.

3.11.3.2 Technology Development

3.11.3.3 Basic Research. Basic Research, in support of the terrestrial environments subarea, fall under the following three categories - cold regions, topography, and seismology. Cold regions research develops first principle models to predict the multispectral signatures of winter terrain surfaces and to provide simulation capabilities for evaluating environmental constraints early in the development cycle of imaging systems.

Topography research develops methodologies to use multispectral and hyperspectral remote sensing in tactical decision aids to support tactical command, control, communications and intelligence (C^3I) requirements for real-time identification of man-made and natural features.

Finally, seismology research efforts are focused on providing a scientific understanding of the processes underlying seismic detection, location and discrimination. Thereby providing new knowledge that will form the basis of formulating innovative techniques to detect, locate and discriminate underground nuclear explosions.

3.12 Ocean Battle Space Environments

3.12.1 Warfighter Needs

The Warfighter needs an affordable, reliable operational capability in all environments and the ability to foresee environmental changes that may affect his capabilities. The ocean environment and its variability greatly affect the operations of the Warfighter, such as movement of equipment and supplies over the beach, cruise missile targeting, or aircraft carrier operations, but also affect the performance of the sensors and systems used by the Warfighter. In particular, since all sensors are affected by the environment in which they operate, knowledge of this environment and its impact on the various sensors available to the Warfighter are critical to his/her choice of sensor(s), ability to gain knowledge of the tactical battlespace and effective delivery of weapons. Knowledge of the ocean battlespace environment thus is important to Joint Warfighter Science and Technology in the areas of dominant battlespace knowledge, combat identification, and joint countermeasure. For the Ocean Battlespace Environments area, these needs translate to the requirements for understanding processes and phenomenology; measurements and mapping; nowcasts and forecasts of ocean variability; and translation of environmental effects to their impacts on sensors,

platforms, structures, and operations. The products in this subarea are designed to increase the Warfighter's knowledge of his battlespace environment so as to unclutter his tactical picture, give him tools to decide on tactics, and give him an advantage over his opponent through exploitation of environmental variability.

3.12.2 Ocean Battlespace Environment Overview

3.12.2.1 Goals and Timeframes. Anticipated conflicts encompassing the ocean battlespace environment involve increasing emphasis on Mine, Special, and Amphibious Warfare in addition to continuing concerns with Anti-Submarine Warfare. Thus, increasing emphasis is on the coastal, shallow, and semi-enclosed sea areas where the ability to predict and simulate the spatial and temporal variability of the environment is a formidable challenge. The fundamental goal is sufficient understanding of the environment's effects on weapons, tactics, and operations, coupled with affordable technologies to observe, describe, and predict those effects. A complementary underlying goal is to encourage and aid the design and use of naval systems that are able to exploit environmental variability to military advantage. Examples of results anticipated in 5 and 10 years are:

FY01	First range dependent, on-scene, adaptive weapon frequency acoustic propagation model. 3-D turbulence model for localized sediment scour in real-time. 1/8 degree North Pacific Oceanographic Prediction System.
FY06	Remote in-situ autonomous coastal sensing system. Autonomous sea floor mapping system. Full spectrum noise model for ASW and MCM frequency bands.

Advances in understanding the ocean environment are critical for the design of new acoustic sensors, acoustic signal analysis and command and control.

3.12.2.2 Major Technical Challenges. Past efforts have been predicated on the construction of data bases supplemented by limited on-site information, and have been aided by large-scale predictive models driven by large-scale observational programs. As the Warfighter's needs move from the open sea to the littoral, and the Battlespace expands in complexity and rapidity of change, the S&T of the Ocean Battlespace Environments continues to develop models for forecasts, but also toward the use of models as a tool to interpolate and extrapolate and as a means to extract maximal information from available and disparate observations. The challenges are to develop surf models for shallow water reconnaissance; models of physical and biological processes which impact acoustic propagation at weapons frequencies; specialized sensing systems for shallow water processes; capabilities for measurement/forecast of coastal optics; remote sea floor mapping capabilities; models of range dependent wave guide propagation; and signal processing to enhance clutter rejection and improve target detection.

3.12.2.3 Related Federal and Private Sector Efforts. With the exception of coastal engineering, industry investments are small. Federal S&T is this area has been

supported for many years by NOAA, NSF, USGS, MMS, NASA, and DoE, but only the first four agencies may have a continuing program in the ocean.

3.12.3 S&T Investment Strategy

Unlike some subareas, not all successful Battlespace Environment products result in formal, large-scale acquisition programs. The S&T investment strategy is therefore predicated on formulation of transition concepts that are highly tuned to the specific needs of the customers of environmental information, and the customers of information that depends on the environment.

The Ocean Battlespace Environment covers the domain from the bottom of the ocean to and including its surface, and from deep water to the beach, including the waves breaking on the beach and the consequent modifications of the beach. Physics, chemistry, biology, geology, engineering, acoustics, hydrodynamics, remote sensing, and associated sensors, observational programs, numerical models, data bases, and prediction technologies are all part of the effort. Seven distinct Program Elements (two in 6.1, the rest in 6.2 and higher) supports the efforts, plus partial funding from many other PEs.

3.12.3.1 Technology Demonstrations. There are no Ocean Battlespace Environment technology demonstrations at the present time. However, S&T developed under this subarea will be utilized in the Joint Mine Countermeasures ACTD involving Navy, Marine Corps, and Army.

3.12.3.2 Technology Development. The programs in this area include oceanography, ocean geophysics and geology, hydrodynamic and sediment processes, and ocean acoustics. These programs provide the key underpinnings for the design of the systems developed in DTOs SE.14.02.N (Lightweight, Broadband Variable Depth Sonar), SE.15.01.ANE (Sensor Signal Processing Technology, and SE.16.01.ANE (Active/Passive Sensor Technology).

3.12.3.2.1 Warfare Support in Littoral Battlespace. DTO SE.32.01.NE. This effort is developing and demonstrating selected capabilities to acquire and exploit meteorological and oceanographical battlespace environmental information required in planning and executing expeditionary, mine, and anti-submarine warfare. Some specific examples include using SPY-1 for doppler radar weather monitoring and extension of acoustic-based ASW capability to Yellow Sea, Persian Gulf, and Baltic Sea.

3.12.3.2.2 Basic Research. There are numerous basic research programs in both Navy and Army that are in direct support of these technology efforts. Notably, the Army's efforts in surface wave prediction have critical applications for Navy and Marine Corps as well as Army. The Navy programs in the areas of physical oceanography, remote sensing, coastal dynamics, geology and geophysics, oceanic biology, underwater acoustics, and the associated observations, data bases, and models are key to enabling the development of the modeling and measuring techniques discussed above. Examples of research programs today that may provide the critical underlayment for tomorrow's applications include topics in non-linear systems and chaos, aerosols, nested models for tactical scale predictions, multi-sensor data assimilation, and non-random distributions of biological sources of optical scattering.

3.13 Lower Atmosphere Environment

3.13.1 Warfighter Needs

Just as in the case of the Ocean Battlespace Environment, the Warfighter needs knowledge of his/her environment, its dynamics, and its impact on his/her sensor and weapon systems. As a consequence, lower Atmosphere Environment emphasis is on specifying and forecasting atmospheric conditions such as temperature, pressure, rainfall, humidity, wind direction and velocity, cloud cover, acoustic and electromagnetic transmission and visibility, all of which directly affect the Warfighter's ability to see and operate ships, aircraft, ground vehicles and most weapons and surveillance systems. Forces conducting warfighting operations must camouflage personnel, weapons systems, aircraft, ground vehicles, equipment, supplies, logistic sites, installations and command, control and communications facilities while continuing to perform their designated mission (low, mid, high conflicts). Forces must be able to confuse, mislead, or evade the threat by reducing the probability of detection, recognition, or identification from threat sensors. Forces must be able to prevent lock or break lock of threat terminal guidance sensors on guided munitions.

As was demonstrated in the Desert Storm operation, weather was the major cause of aborted strike missions, causing 40% of ordnance to be unused over targets and greatly compromised battle damage assessment. Increased knowledge and quality/timeframe of forecasts are needed to ensure that operations occur successfully, with reduced casualties and decreased costs, in system development and asset utilization. A unique DoD need is the requirement to provide operational support in data sparse and data-denied areas. Emphasis must be placed on the development of tailored weather decision aids and on the simulation of weather elements in support of system acquisition, training and wargaming.

3.13.2 Lower Atmosphere Environment Overview

3.13.2.1 Goals and Timeframes. Lower Atmosphere Environment emphasis is to provide tactical-scale atmospheric specification and forecasts on a global basis; develop the real-time tools to assess the environment and its effects on system performance and operations; and develop the techniques of atmospheric measurement, analysis and prediction with seamless, global, continuous coverage. In the concealment area, the emphasis is to develop materials, coatings and thin films which will selectively alter or control reflection and emission of energy which would block or defeat enemy assets across the electromagnetic spectrum. The application of these technologies in smoke, obscurants and camouflage will result in signature management systems that will be truly multispectral, controlling signatures across the electromagnetic spectrum.

FY97	Demonstrate prototype night vision goggles software with performance capable of 70% prediction accuracy. Deliver automated weather analysis system for shipboard and battlefield applications, reducing forecast time by a factor of 5. Develop EM/EO propagation model capable of accurate predictions of communication loss 70% of the time.
FY00	Deliver AI capability for first in weather prediction that exceeds climatology. Integrate infrared target signature models into Decision Aids, reducing, by 50%, the need for flight test hours. Develop passive/reactive signature management system to reduce the detection range of moving vehicles by 50%.
FY03	Develop 3-5 day global ocean-atmosphere coupled prediction model. Develop fully active multispectral signature management and deception system.

Better understanding of the lower atmosphere and its dynamics is critical to Radar (3.1), EO Sensors (3.2), ATR (3.4) and command and control for mission planning.

3.13.2.2 Major Technical Challenges. The challenges are to develop revolutionary new on-scene and remote sensors, data acquisition, data integration and quality control systems, battlescale analysis and prediction capability and artificial intelligence technology for atmospheric product management. The ultimate challenge is to obtain all the required data via remote sensing techniques at the time and spatial resolution required to drive atmospheric specification and prediction models as well as tailored decision aid software. This requirement is based on the need to provide operational support anywhere in the world, including regions of data paucity and data denial.

3.13.2.3 Related Federal and Private Sector Efforts. NSF, NOAA, NASA and FAA participate in lower atmosphere environment S&T. There is a clear distinction between the work described here and the R & D in the broader civilian meteorological community. There is only a very small industrial base in this area.

3.13.3 S&T Investment Strategy

In executing the Lower Atmosphere Environment Subarea, focus is maintained on joint-Service weather requirements and capabilities. Key elements of the investment strategy include the development of new sensor capabilities to support battlefield and global requirements, data fusion and prediction models capable of functioning in a battlefield, data starved or data-denied environment.

3.13.3.1 Technology Demonstrations

3.13.3.1.1 Combat Weather Support. DTO SE.33.01.ANF. The objectives of this program are to demonstrate the ability to fuse battlefield weather information from in-situ and remote observations on land and at sea and validate its utility through participation in operational tests and to demonstrate an artificial intelligence-based "first-

in" weather support capability when the availability of on-site data is negligible or non-existent.

3.13.3.1.2 Smoke, Obscurants, and Camouflage. DTO SE.34.01.A. The objectives of this program are to demonstrate the capability to conceal friendly force assets from threat sensors and acquire enemy low observable targets. Planned demonstrations include obscurant materials to defeat enemy sensor assets and coatings that reduce or eliminate thermal signatures.

3.13.3.1.3 Electro-Magnetic & EO Propagation in Lower Atmosphere. DTO SE.35.01.ANF. The objectives of this program are to demonstrate the accuracy of modeling the electromagnetic propagation environment in support of communications, weapon delivery, surveillance and reconnaissance. A refractivity model will be demonstrated which takes into account the horizontal inhomogeniety of atmospheric conditions in the littoral region; a model will be developed, demonstrated and validated to account for propagation effects resulting from the man-made "haze of war"; and a satellite-based remote sensing capability will be demonstrated for evaluation of propagation effects in data denied areas.

3.13.3.2 Technology Development. Technology advances in all constituent areas of atmospheric science and target signatures are required to achieve the Lower Atmosphere Environment goals. Key thrusts include new ways to observe and predict atmospheric parameters on theater space and time scales, data fusion techniques, improved knowledge of boundary layer physics and battlefield anthropotenic effects for effective EM/EO materials leading to signature suppression coatings across the spectrum from visible to microwave. The focus in this program is on atmospheric measurements, prediction, simulation and the development of system-specific, tailored weather decision aids.

3.13.3.3 Basic Research. Advances in basic research critical to the technology developments in this Subarea include extended forecasting models to directly diagnose critical meteorological parameters for battle regions (cloud ceiling, bases and tops; precipitation intensities; visibility; icing and turbulence); developing improved algorithms to exploit new satellite multi-spectral sounders and imagers for cloud, water vapor and temperature retrieval providing greater vertical resolution than currently available; developing microphysical models to characterize cloud properties that impact DoD systems and operations; utilization of new physics theory, lattice boltzmann techniques, to perform 3D (multiple scattering) radiative transfer in clouds for sensor design and testing; understanding of how energy is exchanged between the surface of the earth and the lowest layers of the atmosphere; investigating the micro millimeter wave properties of metallic films near percolation; and measuring the rough and non-continuous material electro-optic properties.

3.14 Space/Upper Atmosphere Environment

3.14.1 Warfighter Needs

Full Knowledge of the space/upper atmosphere environment is required for the DoD to maintain control of the "high ground" during all levels of engagement. Inadequate knowledge of the space environment, in which and through which the DoD must operate, jeopardizes the safety and effectiveness of warfighting units. At the same

time, the potential for electronic warfare places a high demand on DoD systems to distinguish hostile actions from naturally-occurring events and to respond accordingly. The increased specification and mitigation techniques associated with the Space/Upper Atmosphere Environment goals will be major contributors to dominant battlespace knowledge and superior electronic warfare capabilities.

Recent activities have provided the impetus for improved specification of the C^3I battlespace environment. For example, C^3 outages in Panama, in 1989-1990, facilitated the incorporation of products within this subarea into DoD operations that led to significant cost savings and increased operational access to space assets during Desert Storm (via JCS). Ongoing support in present areas of conflict is now integrated into mission planning to minimize surprise loss of access to GPS and C^3I space assets.

3.14.2 Space/Upper Atmosphere Environment Overview

3.14.2.1 Goals and Timeframes. The technologies developed under the *Specification of the C^3I Battlespace Environment* (SE.36.01.F) are directed towards understanding , assessing and responding to those space/upper atmosphere environmental effects that limit the effectiveness of DoD operational assets. Specific goals and timelines for SE.36.01.ANF and supporting applications are as follows:

FY97	60% improvement in prediction accuracy of C3 outages. 60% improvement in radar target geolocation and target-image reconstruction. 60% increase in satellite anomaly prediction and space environmental mitigation.
FY03	80 % improvement in prediction accuracy of C3 outages. 80% improvement in radar target geolocation and target-image reconstruction. 80% increase in satellite anomaly prediction and space environmental mitigation.
FY07	95% improvement in prediction accuracy of C3 outages and radar target geolocation. 95% improvement in radar target geolocation and target-image reconstruction. 95% increase in satellite anomaly prediction and space environmental mitigation.

Understanding the dynamics of the space/upper atmosphere environment and is critical for the design of space-based sensors and their associated signal and image analysis and the functioning of communication systems.

3.14.2.2 Major Technical Challenges. The theoretical foundations of the space/upper atmosphere environment have steadily progressed since the mid 70's due to the availability of scientific data from DoD, civil and foreign sources. For example, disturbances in C^3I functions have been well correlated with environmental parameters such as solar flares and the intensity of geomagnetic storms and ionospheric plasma density structures. The availability of these parameters, in real-time to space operations, is limited and currently requires proxy data to provide adequate environmental specifications. Current efforts must be geared towards obtaining real-time prediction capability through the development of a better theoretical foundation of space/upper

atmosphere dynamics and effective measuring/sampling techniques. Specific technology development areas include advanced coupled space environmental modeling specifying the geospace environment and dynamic models of spacecraft electrical interactions with space plasmas.

3.14.2.3 Related Federal and Private Sector Efforts. NASA, NOAA, and NSF are involved with the DoD in a strategy to achieve, within the next ten years, a system to provide timely, accurate, and reliable space environment observations, specifications, and forecasts. Included in this strategy is support to the space/upper atmosphere environment for specifying, predicting and mitigating the adverse space environmental effects to C^3I systems. The National Space Weather Program is run under the auspices of the Office of the Federal Coordinator for Meteorological Services and Supporting Research. Agency roles and missions specify that the DoD is responsible for developing physics-based models of the solar-terrestrial environment for operational utility.

3.14.3 S&T Investment Strategy

In executing the Space/Upper Atmosphere Environment R&D program, focus is maintained on specific technology demonstrations in order that the technology effort at the component level can be focused. For the *Specification of the C^3I Battlespace Environment*, these investments include the demonstration of empirical and physics-based models and the technology transition of these models to the primary DoD operational user; that is, the AF Space Command's 50 Weather Squadron (50 WS). Additional investments include developing and testing operational sensors to detect ionospheric scintillations (satellite beacons) and density structures. These investments will provide the 50 WS with an unparalleled capability to specify and predict C^3I outages in support of the Warfighter. Furthermore, these investments benefit the DoD for improved radar target geolocation (see Radar Sensors 3.1), Electronic Upsets (see section 3.8), and satellite anomaly prediction due to interpreting signals and images important to Automatic Target Recognition (see 3.4)

3.14.3.1 Technical Demonstrations. Technology Demonstrations for the Space/Upper Atmosphere Environment are divided into two distinct classes. The first is to evaluate space/upper atmosphere environmental impacts on C^3I functions. While these interactions are fairly well understood, the evaluations provide guidance and facilitate informational dissemination to DoD operations relative to space/upper atmosphere environmental impacts. The second broad objective is to validate that the technologies to specify the C^3I environment are sufficiently developed and understood to be transferred to C^3I operations via the 50 WS.

3.14.3.1.2 Specification of the C^3I Battlespace Environment. These demonstrations, when successful, fulfill DTO SE.36.01.F. These demonstrations are conducted in a building block fashion evolving from the current climatology model of ionospheric scintillation specification (WBMOD), to the initial demonstration of a physics-based specification model in FY97, to the initial demonstration of a physics-based forecast model in FY99, and finally to the initial demonstration of the coupled space-environmental models in FY01. Operational deployment of the coupled models will be complete in FY07. The first demonstration is to validate the Coupled Ionospheric Scintillation Model (CISM) developed to support military satellite communications (MILSATCOM). Validation and operation of the CISM will be enabled by available

Defense Meteorological Satellite Program (DMSP) in-situ ionospheric plasma data and ground-based instrument to monitor irregularity structure. The next demonstration is for validating the Theoretical Ionosphere - Atmosphere Real-time Algorithm (TIARA) to forecast the occurrence of ionospheric scintillations. The final demonstration is for validating those aspects of the advanced coupled space environmental models via the Integrated Space Environmental Model (ISEM) which provides the 50 WS with a fully-coupled geospace specification.

3.14.3.2 Technology Development. Technology advances in all constituent areas of the DTO SE.36.01.F are required to achieve the goals of the Space/Upper Atmosphere Environment program as it pertains to the *Specification of the C^3I Battlespace Environment*.

3.14.3.3 Basic Research. As noted in 3.14.2.2, the major challenges for the Space/Upper Atmosphere Environment battlespace subarea are the theoretical foundations to the currently existing empirical models. Relative to the development of the CISM under DTO SE.36.01.F, the growth rate for ionospheric scintillations must be derived from the generalized Rayleigh-Taylor plasma instability theory. Further, the development of the TIARA algorithm and of the advanced coupled space environment models must provide for a self-consistent flow of energy and matter across distinct models of the geospace environment.

4.0 TECHNOLOGY AREA ROADMAP AND RESOURCES

4.1 Technology Area Roadmap - See Figures VII.3–5.

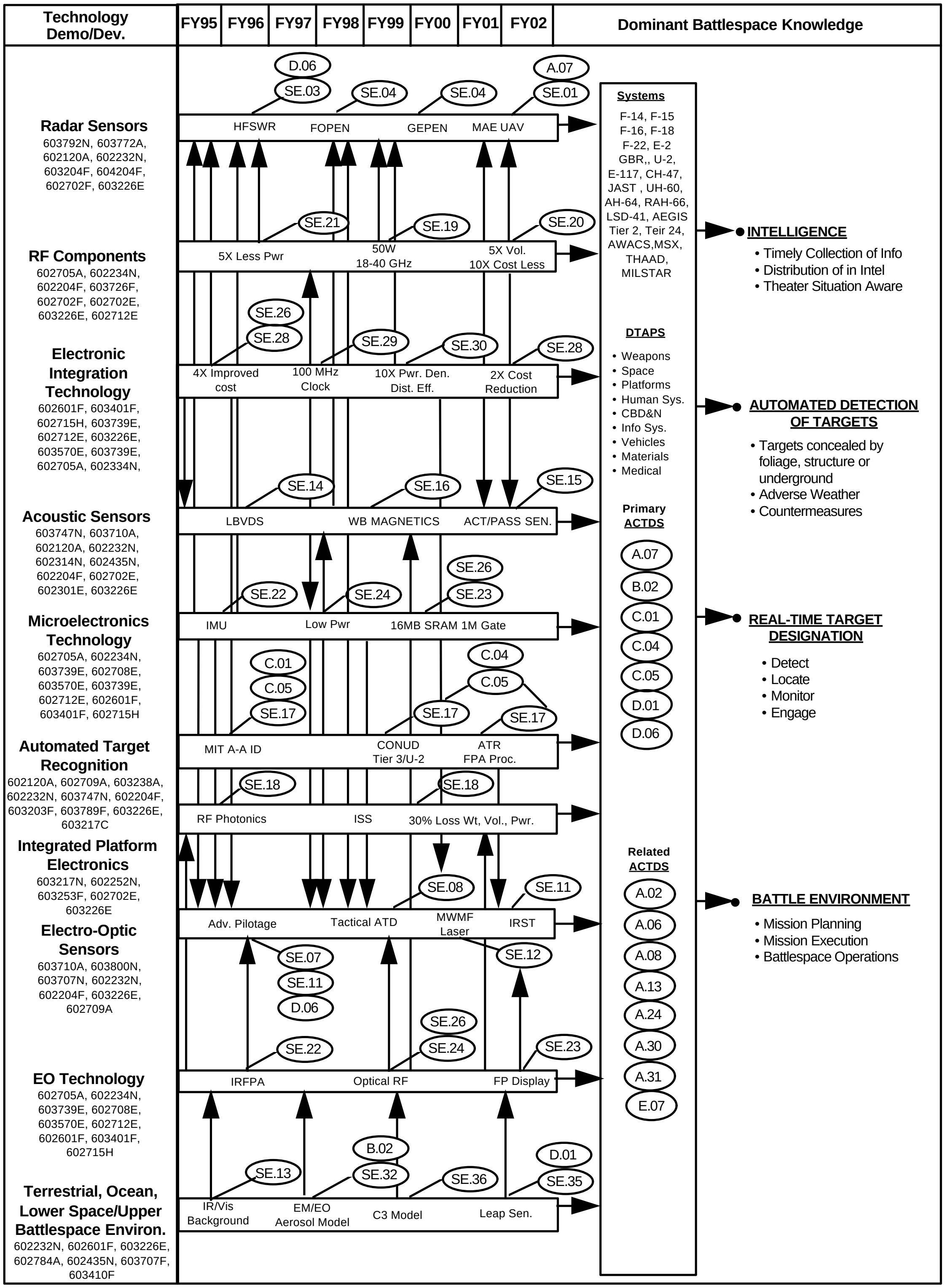


Figure VII.3. Technology Area Roadmap Sensors, Electronics and Battlespace Environment Notional Impact on Dominant Battlespace Knowledge

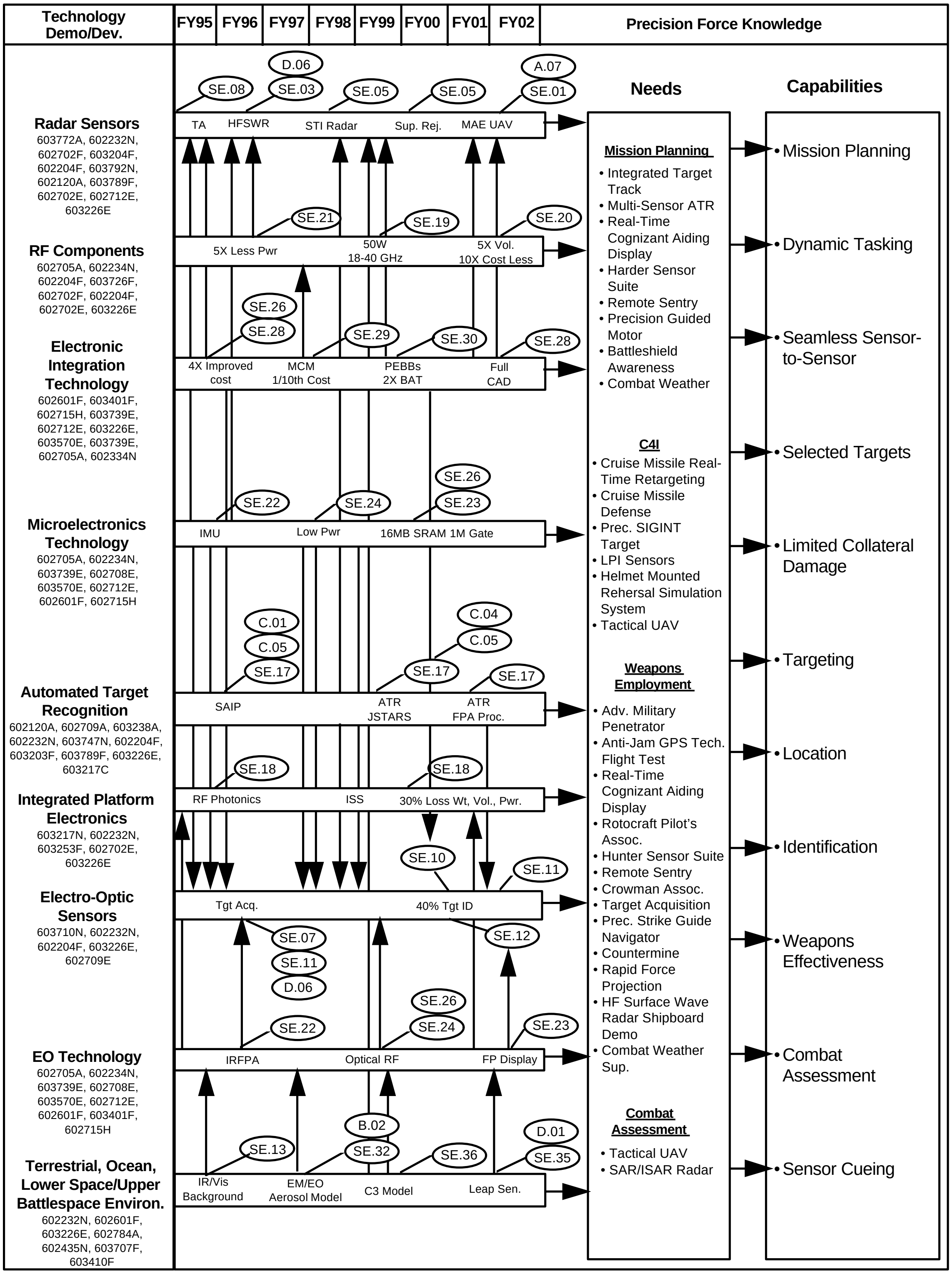


Figure VII.4. Technology Area Roadmap Sensors, Electronics and Battlespace Environment Notional Impact on Precision Force Knowledge

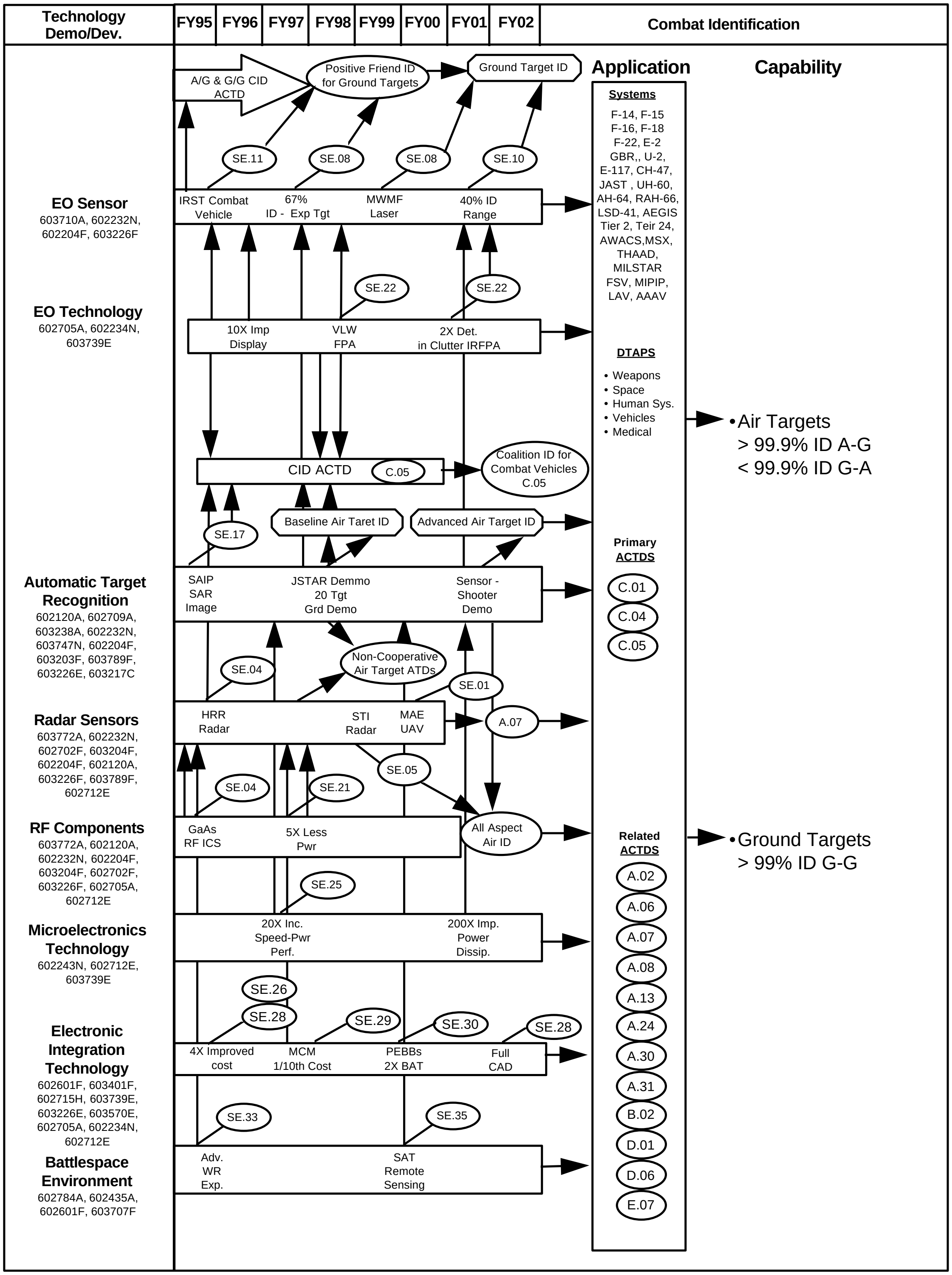


Figure VII.5. Technology Area Roadmap Sensors, Electronics and Battlespace Environment Notional Impact on Combat Identification

4.2 Sensors. Electronics and Battlespace Environment Technology Area Roadmap Resources ($M)

DTOs	Program Element	$ in millions					
		FY1996	FY1997	FY1998	FY1999	FY2000	FY2001
SE.01.01.ANF	0603772A	--	1.0	3.9	5.8	6.7	0
Multi Mission UAV Sensor ATD	0602232N	.2	.6	.3	0	0	0
	0602702F	.2	.3	.3	.3	.3	.2
	DTO Total	.4	1.9	4.5	6.1	7.0	.2
SE.02.02.N	0603792N	3.6	4.2	0	0	0	0
Smart Skin Array ATD							
	DTO Total	3.6	4.2	0	0	0	0
SE.03.02.N	0603792N	6.0	4.0	0	0	0	0
HF Surface Wave Radar ATD							
	DTO Total	6.0	4.0	0	0	0	0
SE.04.01.ANFE	0602120A	1.1	1.1	1.1	1.1	0	0
Penetrating/Identification Radar	0602232N	1.6	1.6	1.6	1.6	1.6	1.6
	0603203F	2.3	2.0	.9	2.5	2.4	2.8
	0602702F	.1	.2	.2	.4	.4	.4
	0603226E	.2	.2	.3	.3	.4	.4
	0602702E	.3	.3	.4	.6	.6	.6
	0603226E	24.7	30.3	31.4	32.5	8.7	0
	DTO Total	30.3	35.7	35.9	39.0	14.1	5.8
SE.05.01.ANFE	0602120A	2.8	2.9	2.8	2.8	0	0
Affordable and Enhanced Radar	0602232N	.9	.9	.9	.9	.9	.9
Signal Processing	0602204F	3.0	3.6	3.9	4.2	5.2	5.5
	0603204F	4.2	5.1	5.8	5.0	5.5	5.5
	0602702F	.3	.4	.4	.4	0	0
	0603789F	.2	.5	.4	.4	0	0
	0602702E	7.4	4.0	1.4	3.8	7.0	10.1
	0602712E	-	6.0	10.0	10.0	2.0	0
	0603226E	6.7	8.3	7.1	7.8	7.9	7.9
	DTO Total	25.5	31.7	32.7	31.1	28.5	29.9
SE.06.01.A	0603710A	--	1.3	5.8	5.8	1.9	0
Air/Land Enhanced Reconnaissance & Targeting							
	DTO Total	--	1.3	5.8	5.8	1.9	0
SE.07.02.ANF	0603710A	4.4	2.4	2.4	0	0	0
Advanced Pilotage	0603800N	2.5	5.0	4.9	0	0	0
	0603707F	.6	.6	.4	0	0	0
	DTO Total	7.5	8.0	7.7	0	0	0
SE.08.02.A	0603710A	6.2	8.3	1.9	0	0	0
Target Acquisition ATD							
	DTO Total	6.2	8.3	1.9	0	0	0
SE.09.02.A	0602618A	1.0	.3	0	0	0	0
North Finding Module							
	DTO Total	1.0	.3	0	0	0	0

Figure VII.6. Sensors, Electronics and Battlespace Environment Technology Area Roadmap Resources

TOTALS MAY NOT AGREE DUE TO ROUNDING

DTOs	Program Element	$ in millions					
		FY1996	FY1997	FY1998	FY1999	FY2000	FY2001
SE.10.02.NF	0602232N	1.3	1.2	1.0	0	0	0
EO Sensor, Fusion, and	0602204F	1.2	1.8	2.0	1.5	1.4	1.0
Targeting	0603203F	.9	.5	1.5	3.0	4.0	4.1
	DTO Total	3.4	3.5	4.5	4.5	5.4	5.1
SE.11.01.ANFE	0603710A	2.7	2.9	0	0	0	0
Advanced Infrared Search and	0602232N	2.4	3.5	2.8	0	0	0
Track (IRST) Systems	0603203F	1.2	1.2	1.2	1.1	0	0
	0603226E	5.2	1.5	1.4	1.4	1.4	1.4
	DTO Total	11.5	9.1	5.4	2.5	1.4	1.4
SE.12.02.ANF	0602709A	.5	1.2	1.4	1.6	0	0
Multi-Wavelength Multi-Function	0602232N	.8	1.0	1.0	0	0	0
	0603203F	.9	.8	2.5	1.7	1.2	1.4
Laser	0602204F	.3	.5	.8	1.8	2.5	3.2
	DTO Total	2.5	3.5	5.7	5.1	3.7	4.6
SE.13.03.NF	0602232N	.1	.1	0	0	0	0
Aircraft Signature Measurement/ Modeling Technology	0602601F	1.6	1.2	1.2	1.4	1.4	1.4
	DTO Total	1.7	1.3	1.2	1.4	1.4	1.4
SE.14.02.N	0602232N	1.2	1.4	1.6	0	0	0
Ltw, Broadband Var. Depth Sonar (Acoustic, Magnetic, Seismic)	0603747N	5.6	10.8	14.6	14.0	14.3	9.0
	0603747N	2.7	1.0	0	0	0	0
	0603747N	.5	.5	.5	0	0	0
	DTO Total	10.0	13.7	16.7	14.0	14.3	9.0
SE.15.01.ANE	0602120A	.8	.9	.9	0	0	0
Sensor, Signal Processing	0602232N	1.2	1.5	1.5	0	0	0
Technology (Acoustic, Magnetic &	0602314N	26.2	28.1	30.1	32.9	32.5	33.3
Seismic)	0602435N	5.6	5.6	5.7	5.9	5.8	5.9
	0603747N	16.0	13.4	19.3	22.6	26.1	24.7
	0602702E	12.9	13.1	16.8	17.0	16.7	14.8
	0602301E	19.9	0	0	0	0	0
	DTO Total	82.6	62.6	74.3	78.4	81.1	78.7
SE.16.01.NE	0602314N	15.0	16.6	16.5	15.3	15.1	15.5
Active/Passive Sensor Tech. (Acoustic, Magnetic, Seismic)	0603747N	14.3	15.1	20.3	23.2	25.9	27.7
	0603226E	2.0	2.6	12.0	12.0	19.4	20.6
	DTO Total	31.3	34.3	48.8	50.5	60.4	63.8
SE.17.01.ANFEC	0602120A	1.1	2.0	1.5	.3	0	0
ATR Dominant Target ID	0602709A	5.5	7.3	5.1	4.1	0	0
	0602232N	4.1	4.1	4.5	5.0	5.1	5.1
	0603747N	15.8	16.0	9.0	5.6	0	0
	0602204F	4.5	5.0	5.2	5.5	5.6	5.9
	0603203F	6.7	5.7	5.6	5.7	6.0	6.2
	0603789F	7.2	7.2	8.4	8.4	8.5	8.8
	0603226E	-	34.2	37.0	21.0	9.5	0
	0603217C	28.6	26.6	33.9	33.9	33.9	33.9
	DTO Total	73.5	108.1	110.2	89.5	68.6	59.9

Figure VII.6. Sensors, Electronics and Battlespace Environment Technology Area Roadmap Resources (cont.)

TOTALS MAY NOT AGREE DUE TO ROUNDING

DTOs	Program Element	$ in millions					
		FY1996	FY1997	FY1998	FY1999	FY2000	FY2001
SE.18.02.NFE	0603217N	10.0	0	0	0	0	0
Integrated Platform Avionics	0602232N	1.1	1.5	.8	0	0	0
	0603253F	14.2	12.1	12.2	13.0	13.1	13.9
	0602702E	9.0	3.0	6.1	4.5	8.4	12.1
	0602702E	-	-	10.0	10.0	10.0	17.9
	0603226E	5.9	7.1	5.9	6.6	6.6	6.6
	DTO Total	40.2	23.7	35.0	34.1	38.1	50.5
SE.19.01.NF	0602234N	1.6	2.2	2.2	0	0	0
Compact High Power RF	0602204F	7.2	7.2	7.7	5.8	5.6	5.2
Transmitters	DTO Total	8.8	9.4	9.9	5.8	5.6	5.2
SE.20.01.AFE	0602705A	.2	.2	.2	.2	.2	.2
Affordable Multi-Chip Modules	0602702F	1.0	1.0	1.0	1.0	1.0	1.0
for Phased Array Antennas	0602204F	1.9	2.0	2.2	2.1	2.2	1.7
	0602702E	.1	0	0	0	0	0
	0603226E	.1	.1	.3	.3	.3	.3
	DTO Total	3.3	3.3	3.7	3.6	3.7	3.2
SE.21.01.FE	0602204F	1.0	1.1	1.0	1.4	.7	.5
Low Power Consumption	0602712E	8.6	17.4	26.4	22.9	20.2	16.0
RF Electronics	0602712E	4.7	9.9	11.3	7.4	8.5	6.6
	DTO Total	14.3	28.4	38.7	31.7	29.4	23.1
SE.22.01.ANFE	0602705A	-	.6	.6	0	0	0
Adv. Infrared Focal Plane Array	0602709A	-	3.2	5.0	5.5	5.4	5.6
	0602232N	1.8	1.8	2.2	2.1	1.4	0
	0602204F	1.0	1.5	1.5	1.7	1.7	1.9
	0603203F	.7	.7	.7	.9	.9	.9
	0602702F	.5	.5	.5	.5	.5	.5
	0603739E	35.6	26.0	9.0	14.0	0	0
	DTO Total	39.6	34.3	19.5	24.7	9.9	8.9
SE.23.01.E	0602708E	48.4	45.0	45.0	45.0	45.0	45.0
Militarized Flat Panel Display	0603570E	26.6	0	0	0	0	0
	0603739E	10.5	5.9	12.3	11.1	11.7	14.0
	DTO Total	85.5	50.9	57.3	56.1	56.7	59.0
SE.24.01.NFE	0602234N	.8	.8	.8	.8	.8	0
Optical Control of Radar,	0602204F	.3	.3	.3	.3	.3	.3
Communication and Electronic	0602712E	15.5	16.1	22.7	26.1	26.9	28.9
Warfare Sys.	0603739E	-	10.2	16.1	29.5	28.5	31.5
	DTO Total	16.6	27.4	39.9	56.7	56.5	60.7
SE.25.01.NFE	0602234N	1.1	1.5	1.4	.7	0	0
High Performance	0603401F	1.0	1.0	1.0	1.5	1.5	1.5
Microelectronics for Signal	0602702F	.8	.8	1.0	1.0	1.0	1.0
Processing and Computing	0602712E	6.6	10.0	14.4	8.1	8.9	6.6
	0602712E	7.3	7.2	4.7	5.9	10.3	13.5
	0603739E	43.8	14.4	5.0	15.9	23.2	25.7
	DTO Total	60.6	34.9	27.5	33.1	44.9	48.3
SE.26.01.AFH	0602120A	.5	.5	0	0	0	0
Radiation Resistant	0602601F	1.8	2.0	2.1	1.5	1.5	1.5
Microelectronics	0603401F	9.0	9.4	8.4	6.7	6.3	2.9
	0602715H	0.7	1.5	1.7	3.0	2.2	2.2
	DTO Total	12.0	13.4	12.2	11.2	10.0	6.6

Figure VII.6. Sensors, Electronics and Battlespace Environment Technology Area Roadmap Resources (cont.)

TOTALS MAY NOT AGREE DUE TO ROUNDING

DTOs	Program Element	$ in millions					
		FY1996	FY1997	FY1998	FY1999	FY2000	FY2001
SE.27.01.E	0603739E	30.1	56.8	65.1	66.6	24.3	0
Microelectromechanical Sys.							
	DTO Total	30.1	56.8	65.1	66.6	24.3	0
SE.28.01.FE	0603739E	-	5.1	11.1	13.0	14.3	15.7
Integrated Design	0602204F	1.0	1.0	1.0	1.0	1.0	1.0
Environment Technology	0603203F	.3	.3	.3	.3	.3	.3
	DTO Total	1.3	6.4	12.4	14.3	15.6	17.0
SE.29.01.FE	0602712E	3.0	4.1	4.2	5.0	4.4	4.6
Electronic Module Packaging	0602712E	9.0	0	0	2.9	4.2	8.5
& Interconnect Technology	0603226E	2.0	0	0	0	0	0
	0603570E	5.2		0	0	0	0
	0603739E	49.7	40.7	61.1	86.4	103.8	126.3
	0602204F	.5	.5	.5	.5	.5	.5
	0602702F	.3	.3	.3	.3	.3	.3
	DTO Total	69.7	45.6	66.1	95.1	113.2	140.2
SE.30.01.ANFE	0602234N	2.3	2.8	2.1	2.2	2.2	2.1
Energy Storage and	0602334N	.5	.5	.5	.5	.6	.5
Distribution Technology	0602334N	.1	.1	.1	.1	.1	.2
	0602334N	1.8	2.3	1.6	1.6	1.5	1.5
	0602204F	.2	.2	.2	.2	.2	.2
	0602712E	3.0	4.1	4.2	5.0	4.4	4.6
	0602712E	9.0	0	0	2.7	4.2	6.5
	DTO Total	16.9	10.0	8.7	12.3	13.2	15.6
SE.31.01.A	06022709A	3.2	3.3	3.3	0	0	0
Adv. Optics and Display							
Application							
	DTO Total	3.2	3.3	3.3	0	0	0
SE.32.01.ANE	0602306A	1.6	1.7	1.8	1.9	0	0
Warfare Support in the	0602784A	.4	.4	.4	.4	.4	.4
Littoral Battlespace	0603784A	-	-	2.0	2.5	3.0	3.0
	0602315N	.7	1.0	.7	.6	.5	.5
	0602435N	3.0	3.0	3.0	3.0	3.0	3.0
	0603226E	6.4	10.0	10.1	10.0		
	DTO Total	12.1	16.1	18.0	18.4	6.9	6.9
SE.33.01.ANF	0602784A	.9	.9	1.0	1.0	0	0
Combat	0602435N	2.1	2.0	2.0	2.1	2.1	2.1
Weather Support	0602601F	1.1	1.2	1.2	1.3	1.3	1.4
	0603707F	.6	.3	.2	0	0	0
	DTO Total	4.7	4.4	4.4	4.4	3.4	3.5
SE.34.01.A	0602622A	1.0	1.0	1.0	0	0	0
Smoke, Obscurance and							
Camouflage							
	DTO Total	1.0	1.0	1.0	0	0	0
SE.35.01.ANF	0602435N	2.1	2.2	2.2	2.2	2.3	2.3
Electromagnetics &	0602601F	1.6	1.3	1.2	1.4	1.4	1.5
Electro Optical	0603707F	.7	1.0	1.3	1.4	1.6	1.6
Propagation in the							
Lower Atmosphere							
	DTO Total	4.4	4.5	4.7	5.0	5.3	5.4

Figure VII.6. Sensors, Electronics and Battlespace Environment Technology Area Roadmap Resources (cont.)

TOTALS MAY NOT AGREE DUE TO ROUNDING

DTOs	Program Element	$ in millions					
		FY1996	FY1997	FY1998	FY1999	FY2000	FY2001
SE.36.01.F Specification of the C^3I Battlespace Environment	0602601F	2.5	2.4	2.2	2.2	2.2	2.3
	DTO Total	2.5	2.4	2.2	2.2	2.2	2.3

Figure VII.6. Sensors, Electronics and Battlespace Environment Technology Area Roadmap Resources (concluded)

TOTALS MAY NOT AGREE DUE TO ROUNDING

SENSORS, ELECTRONICS AND BATTLESPACE ENVIRONMENT ACRONYMS

ACC	Access Control Center
ACC	Air Combat Command
ACTD	Advanced Concept Technology Demonstration
ADC	Analogy to Digital Converters
AEW	Airborne Early Warning
AIN	Army Interoperability Network
AMW	Amphibious Warfare
AN/UYS2a	Navy Signal Processor
ARL	Army Research Laboratory
ARPA	Advanced Research Projects Agency
ASW	Anti-Submarine Warfare
ATD	Advanced Technology Demonstration
BMDO	Ballistic Missile Defense
CAD	Computer Aided Design
CECOM	U. S. Army Communications-Electronics Command
CMD	Cruise Missile Defense
CMOS	Complementary Metal Oxide Semiconductor
CMOS/SiGe	Complementary Metal Oxide Semiconductor/Silicon Germanium
CMOS/SOI	Complementary Metal Oxide Semiconductor/Statement of Intent
COTS	Commercial Off-The-Shelf
DAC	Digital to Analogy Converters
DDR&E	Draft Synthetic Environment Strategic Plan
DDS	Direct Digital Synthesizer
DMS	Desorption Mass Spectroscopy
DNA	Defense Nuclear Agency
DoE	Department of Energy
DSRC	Defense Science Research Council
DTAO	Defense Technology Analysis Office
EEPROM	Electronically Erasable Programmable Read-Only-Memory
ESCAN	Electronically Scanned
ETC	Echo Tracking Classifier
EW	Electronic Warfare
FCR	Fire Control Radar
FNMOC	Fleet Numerical Meteorology and Oceanography Command
FOV	Field-Of-View
Ga	Gallium
GaAs	Gallium Arsenide
GaN	Gallium Nitride
GBR	Ground Based Radar
GE	General Electric
GHz	Gigahertz (1 billion herta)
GMR	Giant Magneto resistive
HF	High Frequency
HFSWR	High Frequency Surface Wave Radar
HTS	High Tc Superconductor
I/O	Input/Output
IBM	International Business Machines
ICs	Integrated Circuits
JLOTS	Joint Logistics Over the Shore
LCD	Liquid Crystal Display
LOSIM	Low Observable Simulation
LWIR	Long Wave Infrared
MBE	Molecular Beam Epitaxy
MCM	Mine Countermeasures
MCM	Multi-Chip Module
MEMs	Microelectromechanical Systems
MGRCC	Very High Resolution Littorlal Prediction System
MHz	Megahertz
MIW	Mine Warfare
MMIC	Monolithic Microwave Integrated Circuits
MMS	Marine Mineral Survey
MMW	Millimeter Wave
MPM	Microwave Power Module
MWIR	Mid-Wavelength and/or Long-Wavelength Infrared
NASA	National Aeronautics and Space Administration
NAVAIR	Naval Air Command
NAVOCEANO	Naval Oceanographic Office
NAVSEA	Naval Sea Systems Command
NDRO	Nondestructive Readout
NEXRAD	Next Generation Radar
NOAA	National Oceanic and Atmospheric Administration

NRaD	Naval Command Control and Ocean Surveillance Center Research Development, Training and Education Division
NSF	National Science Foundation
NSW	Naval Special Warfare
OMCVD	Organo-Metallic Chemical Vapor Deposition
OMICs	Opto-Microwave Integrated Circuits
ONR	Office of Naval Research
OTH	Over-The-Horizon
OUSD	Office of the Under Secretary of Defense
PM	Product Modeling
PM	Program/Project/Product Manager
RAES	Research, Evaluation and System Analysis Facility
RAM	Random Access Memory
RAM	Reliability, Availability, and Maintainability
RASSP	Rapid Prototyping of Application Specific Signal Processors
RCS	Radar Cross Section
RF	Radio Frequency
RF ICs	Radio Frequency Integrated Circuits
RL	Rome Laboratory
RTTs	Resonant Tunneling Transistors
S&T	Science and Technology
SERDP	Strategic Environmental Research and Development Program
SiC	Silicon Carbide
SiGe	Silicon-Germanium
SOI	Silicon-on-Insulator
TFSOS	Thin Film Silicon-on-Sapphire
TI	Texas Instrument
UAV	Unmanned Airborne Vehicle
UHF	Ultra High Frequency
USGS	United States Geological Survey
USSPACECOM	U.S. Space Command
USSTRATCOM	U.S. Strategic Command
UWB	Ultra Wide Band
VHR	Very High Resolution
WAS	Wide Area Surveillance
WES	Waterways Experiment Station

VIII. FY 1997 DEFENSE TECHNOLOGY AREA PLAN FOR SPACE PLATFORMS

1. INTRODUCTION

1.1 Definition/Scope

The Space Platforms technology area includes efforts devoted to satellite systems and launch vehicles. Here, satellite refers only to the support platform as opposed to the mission payload, and the launch vehicles subarea includes ballistic missile technologies. There are two major subareas, as shown in Figure VIII.1: (1) Space Vehicles, focused on thermal management, structures, survivability, GN&C, power, and astronics (those aspects of electronics, sensors, communications, and satellite control technology required by the space environment) and; (2) Space Propulsion, which includes booster, orbit transfer and satellite propulsion. Space sensors, electronics, and communications payload technologies, unique to space, are part of the Sensors and Electronics panel and the Information Systems and Technology panel but are included here for completeness of space demonstrations.

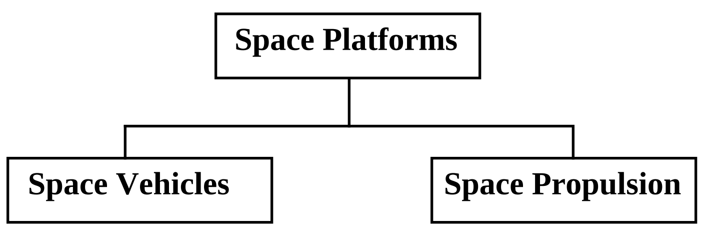


Figure VIII.1. Planning Structure—Space Platforms Technology Area

The Space Vehicles subarea includes all of the technology efforts contained in the Space Vehicles section of the 1995 Air and Space Vehicles DTAP along with space power from the 1995 Aerospace Power and Propulsion DTAP. However, the flight experiments technology effort has been incorporated into the technology demonstrations section of the 1996 DTAP. The Space Propulsion subarea is the corresponding portion of the 1995 Aerospace Power and Propulsion DTAP. See Resource Appendix for funding of this Defense Technology Area. The set of DoD S&T technology efforts included in this panel area encompasses the following:

Space Vehicles:

- **Thermal Management**: focused on heat transfer/dissipation and cryocooler technologies for all satellite applications.
- **Structures**: focused on the development of structures and structural control technology for DoD spacecraft and launch vehicles. Work on tankage for launch

vehicles and inflatable structures for antennae or optics is now being included in this technology effort. Work on nozzles and cases for rocket systems is not included here but is included later in the Space Propulsion Subarea. Structures for hypersonic vehicles are not included in Space Platforms, but are covered under Air Platforms. In the same vein, work on Ground Based Anti-Ballistic Missile Missiles is not covered here, but is covered in the Weapons area.

- **Survivability**: focused on surviving natural and hostile space environments using multiple strategies and active and passive techniques that may be employed in space vehicle design to improve on-orbit survivability.
- **Guidance, Navigation and Control (GN&C):** focused on advanced GN&C science and technologies for launch from Earth, Earth orbit and free space. GN&C encompasses both launcher/missile guidance and spacecraft guidance in the unique gravity free/gravity controlled space environment. GN&C also involves the precise timing and time transfer technologies enabling the Global Positioning System (GPS), and advancing the technologies in GPS applications.
- **Spacecraft Power**: focused on the generation, storage, and distribution of electrical power onboard spacecraft. This technology subarea covers the particularly stressing spacecraft problem of radiation hardened solar cells and power systems and long life energy storage systems.
- **Astronics**: focused on adapting space unique technology including sensors, electronics, communications and satellite control technologies.

Space Propulsion:

The Integrated High Payoff Rocket Propulsion Technology Program (IHPRPT) is a tri-service/NASA/industry program designed to develop and demonstrate innovative and revolutionary technologies that will dramatically advance state-of-the-art propulsion technology. IHPRPT has been established to strengthen the propulsion technology base for application in U.S. military, civil, and commercial programs and 1995 marked the first year of this program. Participants in the IHPRPT program include the US Army, US Navy, US Air Force, NASA and industry. All participants are working together to achieve a common set of national propulsion goals.

- **Boost Propulsion**: focused on large thrust producing engines and motors for first and second stage launch vehicle environments. Boost propulsion programs address both space boost and strategic (ballistic missile) boost technology development.
- **Orbit Transfer**: focused on efficient chemical and non-chemical orbit transfer propulsion systems which move payloads from low-Earth orbit (LEO) to operational orbit altitudes.
- **Satellite Propulsion**: focused on spacecraft propulsion for maneuver and station keeping that includes both chemical and non-chemical propulsion, e.g., solar electric and solar thermal.

1.2 Strategic Goals

The strategic goal is to exploit space platforms to provide warfighters with critical information and global communications. Space allows a whole range of critical military functions without the usual limitations associated with denied areas or geographical remoteness. Information provided U.S. military personnel by space-based systems includes: weather, forces location/movement, environmental monitoring, transportation routes, and advanced warning on weapons deployment. The essence of the DoD's use of space is as a domain in which huge quantities of information can be both gathered and delivered directly to the warfighter.

The goal for Space Vehicles is to construct spacecraft which are lighter, smaller, autonomous, require less power and have a longer functional lifetime with lower lifecycle costs while maintaining and improving overall system performance and operation. Achievement of this goal is grounded in the basic technologies of structures, power, electronics, etc. and will only be accomplished as these technologies are strongly supported and demonstrated for space vehicle application.

Space Propulsion is a critical supporting technology that has a large impact on the lower cost goal by providing for cheaper access to space. Both boost and orbit transfer propulsion technology developments are directed to this effort. Operations are also dependent on space propulsion technologies including timely access and on-orbit maneuvers. Figure VIII.2 identifies key technology transition/transfer opportunities in the Space Platforms area that will continue to enhance and enable the U.S. military dominance of the high ground. Included are commercial systems whose more frequent new starts and shorter development cycle time enable the rapid evolution of satellite technology. A list of acronyms can be found at the end of this chapter.

1.3 Aquisition/Warfighting Needs

U.S. space assets support five of the twelve Joint Warfighting Operational Needs/Capabilities. These five are (1) Dominant Battlespace Knowledge, (2) Information Warfare, (3) Counterproliferation, (4) Precision Force, and (5) Joint Theater Missile Defense. Dominant Battlespace Knowledge is supported by the following space missions: surveillance; intelligence; communications; mapping, geodesy, and charting; environmental monitoring; and command and control. Information Warfare is supported by the satellite control and space control missions, Counterproliferation by surveillance and intelligence missions, Precision Force by the navigation mission and Joint Theater Missile Defense is supported by the surveillance, intelligence, communications, and command and control missions. All of these space missions are in turn supported by the space launch and space system control missions, and the space unique aspects of system integration and acquisition. Space-related acquisition amounted to $13.5 billion in FY95.

	Years		
	2000	**2005**	**2010**
Space Vehicles	SBIRS High - 32 bit Rad Hard Processors - MWIR Focal Planes NPOESS - MAGIC - Solar Cells - Batteries PCS/Cellular Systems - Sat Comm	SBIRS Low - Cryocoolers - LWIR Focal Planes - Rad Hard Processors GPS IIF - GN&C - MAGIC Advanced EHF - MILSATCOM - 32 bit Processors - RF & Laser X-Links Space Based JSTARS - Sensors - Electronics 2nd Generation PCS - Sat Comm	Space Based AWACS HEXSAT Space Based Laser Systems - Precision Platforms - Space Power
Space Propulsion	RS-27 Upgrade EELV Tech Insertion Titan SRMU Solar Electric Propulsion	Environmentally Clean Motors Russian Engine Tech Reusable Cryo Engine Shuttle Replacement	Rapid Response ELV Improved Russian Engine Technology Trans Atmospheric Vehicle

Figure VIII.2. Space Platforms Technology Transition Opportunities

The Space Platforms technology area provides new and improved technologies which support, expand, and/or enable all of the above warfighter needs and space mission areas. The development of affordable, expendable boost and strategic propulsion systems will enhance the strategic agility of the United States space forces. The operational improvements for boost and orbit transfer systems by the years 2000, 2005, and 2010 include 9%, 16%, and 22% increases in payload capability or launch cost reductions of 19%, 31%, and 42%. Long-life, responsive spacecraft/satellite propulsion systems (solar electric, solar thermal, chemical) support the warfighter by enhancing strategic maneuverability and reliability of reconnaissance/surveillance and communication capabilities. Satellites in geosynchronous orbit will be able to extend their on-orbit life up to 45%, increase repositioning capabilities by a factor of 2-5 depending on the size of the satellite, or increase useful mission payload mass by 10-30%. In addition, this technology area supports acquisition by providing advanced electronic components which are lighter, faster, require less power, survive solar maximum conditions, etc. Advanced components being considered for MILSTAR for example, will produce a lighter satellite that allows use of a smaller launch vehicle resulting in a savings of $150M per launch. Individual improvements presented in this document are measured against current technology as opposed to planned improvements or future developments.

2. DEFENSE TECHNOLOGY OBJECTIVES (DTOs)

2.1. Space Vehicles

SP0106FC	Cryogenic Technologies
SP0207F	Thermal Management Technology
SP0306NF	Space Structures and Control
SP0506F	Large Precise Structures
SP0606NFH	Space Systems Survivability
SP0703FE	Space-Based Guidance, Navigation, and Control (GN&C)
SP0806FCH	Space Power Technology
SP0901F	Satellite Control
SE2601AH*	Radiation-Resistant Microelectronics (includes Space Electronics)
SE22.01ANFE*	Advanced IRFPA (Includes Space Sensors)
IS2301AFNC*	Digital Warfighter Communications (includes Satellite Communications)

2.2. Space Propulsion

SP1006F	Spacelift Propulsion
SP1106F	Orbit Transfer Vehicle Propulsion
SP1206F	Spacecraft/Satellite Propulsion

2.3. Joint Warfighter Science and Technology Plan (JWSTP)

A34	(Dominant Battlespace Knowledge) Multimission Advanced Ground Intelligent Control (MAGIC) ACTD

*DTO's marked with an asterisk are not officially reported here in the Space Platforms Area but are reported in other areas. They do, however, represent space unique applications of considerable importance to the Space Platforms Area.

3. TECHNOLOGY DESCRIPTION

3.1 Space Vehicles

3.1.1 Warfighter Needs

Space Vehicle technology goals translate into payoffs to the warfighter in terms of increased warfighter capabilities. Payoffs to satellite systems include higher performance, lower cost, longer life, and increased reliability for existing and new

satellite families. This technology area also provides solutions to numerous AFSPC deficiencies. Examples of deficiencies include: inadequate near Earth coverage; high O&M costs; inadequate satellite element set accuracy; inadequate terminal mobility; insufficient communications capacity; accuracy of data; vulnerability of ground facilities; and slow deployment of space assets. Advanced space sensor, precision orbital structures, and cryogenic technologies will help provide all weather, day/night operation, and detection of airborne targets down to cruise missile size. GPS technology advances allow for improved targeting of Earth-based objects and precision strikes. Sensor, precision orbital structures, and cryogenic technologies are applicable to SBIRS, SMTS, NPOESS, space based JSTARS and AWACS alternatives and NASA EOS. Space power transition targets include NPOESS, GPS IIF, SBIRS, MILSTAR, space based JSTARS and AWACS alternatives, FLEETSATCOM, and SMTS. Communications transition targets are MILSATCOM (e.g., FLEETSATCOM and MILSTAR), as well as any mission requiring high data rate transmission. The USAF has taken steps to transition to a common core Telemetry, Tracking, and Control (TT&C) in the next few years which will support multiple satellite families. Satellite control technology is directed on evolving the Core to support existing and future warfighter needs and migrating autonomy for satellite control from the ground segment to the space segment. GN&C technology supports precision navigation and autonomy for the satellite relieving large O&M costs, as well as performing the guidance portion for global delivery of precision conventional warheads. Survivability technology advances include advanced hardening techniques, development of radiation and other environmental effects models, and a satisfactory method to allow COTS devices to operate properly in space. These will permit any space system to be produced at lower costs and to function longer and more reliably. In addition to the listed systems, advanced electronics technologies enable future space systems that are envisioned to support the warfighter into the 21st century.

3.1.2 Space Vehicles Overview

3.1.2.1 Goals and Timeframes

	YEAR 2000
Thermal Mgmt	- Reduce component mass by 15%; increase lifetime to 5 years - Increase heat transport by 25% - Decrease subsystem mass by 5% - Decrease electronic component temperature by 10°C
Structures	- Reduce satellite structural mass by 40% and simultaneously reduce cost by more than 10% - Reduce launch vehicle structural subsystem cost by 25% - Decrease dynamic launch impulse loads to which a satellite is subjected by a factor of 5 - Reduce pyrotechnic-shock to which satellites are subjected by more than two orders of magnitude - Decrease on-orbit vibrations experienced by payloads by a factor of 10
	YEAR 2005
Survivability	- Reduce discrepancies between model predictions, ground and space flight test values for radiation effects - Develop design guidance for hardening sensors against directed energy - Allow adoption of COTS components
GN&C	- GPS (sat) receivers with 10m absolute positioning; improved timing; 7 W power, weight 0.7 kg, direct Y-code acquisition - Gyroscopes with <0.01 deg/hr drift, volume 2000 cm^3, power 10 W, weight 0.45 kg, >100,000 hr MTBF - Star trackers with 1 arcsecond pointing accuracy, volume 1640 cm^3, 5-6 W power, weight 0.27-3 kg - Autonomous sat Navigation capable of <50 m positioning uncertainty
Power	- Develop solar arrays which are 28% efficient, produce 100 Whr/kg, cost $500/W - Develop 120 Whr/kg rechargeable battery
Electronics	- Increase processor throughput by a factor of 10 - Reduce weight by a factor 10 - Develop ultra-thin high density interconnect technology - Demonstrate space qualified components with submicron feature size
Sensors	MISSILE DETECTION - Increase array sensitivity by a factor of 20 - Reduce cost (per detector) by a factor of 40 COLD BODY DETECTION - Increase array sensitivity by factor of 10 - Increase detection range by factor of 3 - Reduce cost (per detector) by 75%
Communications	- Develop RF crosslinks with reduced weight by a factor of 10 and an increase in performance by a factor of 15 - Develop, demonstrate and deploy advanced comm modems reducing weight from hundreds of pounds to ounces
Satellite Control	- Reduce ground support manpower by 50%; Reduce sustainment costs by 40%

Thermal Mgmt	- Reduce component mass by 50% - Reduce specific power by 40% (W input/W cooling) - Improve reliability to 98% - Increase heat transport by 75% (W·m) - Decrease subsystem mass by 15%; - Decrease required heater power up to 75%
Structures (2011)	- Reduce satellite structural mass by 75% and cost by more than 25% - Reduce launch vehicle structural subsystem cost by a factor of 10 - Decrease dynamic launch loads to a satellite by a factor of 20 - Decrease on-orbit disturbances experienced by payloads by a factor of 100 - Provide precision deployable RF (.5 to 10 GHz) structure capable of rms antenna element position knowledge on the order of lambda 50 (or sub-array pattern matching to 40 dB from peak) over antenna structure sizes with longest dimension from 100 to 500 wavelengths
Survivability	- Improve ground based debris catalogue to include debris down to 1 cm - Perform debris measurements in space
	YEAR **2005**
GN&C	- GPS receivers with 5-10 m absolute positioning, volume less than 200 cm^3, requiring less than 7 w power, and weighing less than 0.5 kg, AJ, anti-spoof - Gyroscopes with less than 0.0005 deg/hr drift, volume less than 200 cm^3, requiring less than 8 w power, weighing less than 0.4 kg and having 20 year life - Star trackers with less than 1 arcsecond pointing accuracy, volume less than 1310 cm^3, requiring less than 5 w power, and weighing less than 2.5 kg - Autonomous navigation capable of 30-40 m position accuracy
Power	- Develop solar arrays which are 35% efficient, produce 120 W/kg, 15 to 30 yr life at 1000 to 4000 km altitude - Develop 175 Whr/kg rechargeable battery - Develop energy storage elements with cycle limits capable of 15 to 30 year life at orbital altitudes on the order of 1000 to 4000 km
Electronics	- Increase throughput by 2 orders of magnitude - Decrease power consumption by 90% - Reduce cost with space qualified versions of COTS parts
Sensors	MISSILE DETECTION - Increase array sensitivity by factor of 40 - Reduce cost (per detector) by a factor of 200 COLD BODY DETECTION - Increase array sensitivity by factor of 100 - Increase detection range by factor of 10 - Reduce cost (per detector) by a factor of 20 - Reduce array costs by an order of magnitude
Communications	- Develop and demonstrate optical crosslinks reducing weight by a factor of 20 at GEO to LEO distances - Develop light weight multiband transceiver payloads for ground and crosslinks
Satellite Control	- Reduce ground support manpower by 66% manpower; Reduce O&M costs by 50%

3.1.2.2 Major Technical Challenges. The technical challenges in developing advanced technologies and subsystems for Space Vehicles focus on reducing weight, size,

and cost; isolating vibration; increasing power efficiency, reliability, and overall spacecraft lifetime. The challenges associated with each technology are as follows:

- Thermal Management: minimizing material stresses, mass, internal parasitics, and increasing the motor and cold interface heat transfer efficiencies; eliminating sources of contamination and friction; developing improved adaptive and passive structural damping; develop novel approaches to reduce cryocooler vibrations; the development of rapid, reliable start-up and long term operation capability of two phase capillary devices in zero-g and adverse-g environments; developing advanced materials to dissipate heat fluxes from microelectronic devices and capillary wicks with less than 1 micron pore size; and improving flexible or rotatable joints for deployable radiators.

- Structures: structural isolation without constraints on rattle space (clearance); understanding dynamics arising from interactions between the space environment, structural materials, individual components, control systems, the launch vehicle, and spacecraft; cost effective manufacturing techniques; development of rapid non-pyrotechnic release mechanisms and high fidelity, ground-based experimental simulations; increased reliability/durability of Multi-Functional Structure connections; and deployable, large lightweight structures.

- Survivability: develop radiation tolerant space devices and systems; reduce space-use COTS safety factor with improved understanding of basic radiation effects phenomena; improve reliable high precision survivability simulations; develop miniaturized laser and radar threat detectors, optical systems jamming protection; characterize space debris hazards.

- GN&C: mitigate or reduce radiation exposure and plasma effects; eliminate Ring Laser Gyro (RLG) mechanical dithering; improve RLG mirror durability; improve light sources, coil selection, and windings for interferometric fiber optic gyros (IFOGs); improve micromachining processes; laser tracking; obtaining accurate ephemeris data; and the hardware/software interface for autonomous navigation.

- Power: increased compatibility and applicability of advanced materials in the space environment; more efficient photovoltaics; viability of manufacturing; feasibility of solar thermal conversion; limits on high temperature power conversion; highly reactive chemicals; runaway electrochemical reactions; and life limiters in energy storage (e.g., electrode wear).

- Space Electronics: increasing space radiation hardness of recently available small feature size, high performance electronics technologies; advanced packaging to dissipate heat in a vacuum without out-gassing; advanced insulated device technologies; and integrated MEMs.

- Space Sensors: increase the operating temperature of sensors; improve manufacturability of large size focal plane arrays; and significant reduction of sensor readout noise.

- Satellite Communications: develop high capacity dynamic optical communications system area networks; develop a small, adaptable (to numerous wavefronts) and efficient modem; and improved ability to manufacture ultra light-weight, higher frequency antenna and GaAs PHEMT MMICs, and low power

high speed CHFET (Complementary Heterojunction Field Effect Transistor) custom integrated circuits.

- Satellite Control: overcome vendor-specific dependencies in COTS software; exploiting distributed artificial intelligence capabilities; develop integration of an intelligent trainer with a multi-satellite ground system; use of model-based reasoning and machine learning for anomaly resolution; reducing development and sustainment costs when DoD does not drive the market; and reliable, verifiable artificial intelligence-based systems for autonomous satellites.

3.1.2.3 Related Federal and Private Sector Efforts. Outside of the DoD, the primary government organizations funding Space Vehicles technology development are NASA and DOE. National systems also make a huge investment in space vehicles technology. Formal coordination with NASA, DOE, DOC and DOT is provided through the Space Technology Interdependency Group (STIG). Historically, the NASA investment matches that of the DoD in many of the technologies, while the DOE investment is considerably smaller. Joint program planning and management of technology development (e.g., NASA/DoD IPT) is coordinated among these organizations and the user community to ensure maximum return on government investment of research and development funding. The related NASA programs of greatest relevance are the New Millennium Program and the Small Satellite Technology Initiative. Various pervasive technologies, such as space power, thermal management, and structures are closely coordinated with the responsible NASA technology centers. Industry is estimated to be investing $220 million of their IR&D funds in related space technology. This work is typically focused on developing a competitive capability for near and far term corporate goals. Additionally, there are focused commercial ventures for space-based systems, such as communication and imaging satellites, that complement these efforts. The recent appearance of a strong well-capitalized commercial presence in space allows DoD to leverage advances in these systems. Commercial space manufacturers' private capital, short development cycle, and frequent new starts permit a new arena for rapid maturation of space platform technology. The DoD has formed CRDAs (Cooperative Research and Development Agreements) with the commercial sector to provide opportunities for space demonstration of the technology and to jointly share in the cost of development in some areas, such as energy storage. Industry has plans for both highly autonomous spacecraft and architectures for large, distributed networks of satellites. Similar advances are occurring in the international arena as well.

3.1.3 S&T Investment Strategy

3.1.3.1 Technology Demonstrations. The Space Vehicles technology demonstration program is based on three major demonstration concepts as well as individual component and subsystem technology demonstrations in support of the DTOs for this subarea.

The first effort is the USAF Integrated Space Technology Demonstration (ISTD) program, which will demonstrate medium risk, high payoff system and payload concepts through the design, integration, test and evaluation of emerging technologies in real world environments. The focus is the demonstration of advanced technologies with maximum payoff to military space systems operators and users. Major elements of ISTD include the transition of new technologies from the laboratory to integrated systems, the

employment of leveraged flight opportunities to address both technology and system level issues as economically as possible, and demonstration of laboratory technologies in support of specific military space objectives. Flights will occur every three to five years. Specific current objectives include: demonstration of the military value of near real time tactical imagery derived from commercial and civil providers; the design, development, and demonstration of an affordable space-based hyperspectral imaging payload for tactical target detection; and development of innovative ways to support future tactical imaging payloads on a wide range of commercial space platforms. Success will provide a $\geq$ 50% reduction in the time required to field a new imaging system, from more than 7 years to 3 1/2 years; an overall reduction in the time (from days to only a few hours) required to bring tactical imagery to the tactical users; and a potential 50% reduction in optical system payload weight (from 500 kg to 200-300 kg), which will in turn reduce launch costs. The first ISTD flight will demonstrate targeted FY00 goals within the following DTOs: Cryogenic Technologies (SP01), Space Structures and Control (SP03), Space Electronics (SE26), Space Sensors (SE22), and Satellite Communications (IS23). These goals include reduced cryocooler mass, reduce structured mass and advanced comm modems. These programs directly support the Air Force Space Command, including the Space Warfare Center, and military users of tactical space imagery.

The second part of the demonstration program is the USAF MightySat. This program is a fast-paced, aggressive series of space experiments and demonstrations that focus on experimenting with and demonstrating a small number of new, emerging Air Force technologies on each flight. Each MightySat mission focuses on three objectives: demonstrating emerging technologies, measuring the technologies' suitability, determining the reliability, and removing or reducing the risk of using new technologies for space acquisition. The MightySat approach of providing annual, low-cost access to space ensures the ability for emerging, space-ready technologies to acquire space heritage. Each MightySat mission will take about 24 months from conception to launch and provides for one year of on-orbit mission operations. The first MightySat is schedule to launch on the Space Shuttle in December 1996. This flight supports the following DTOs: Advanced Structural Components (SP03), Space Power Technology (SP08), and Space Electronics (SE26). The second MightySat is schedule for launch in Jan 98, with schedule launches every year thereafter. MightySat-2 supports Advanced Structural Components (SP03), Guidance, Navigation, and Control (SP07), and Space Sensors (SE22). MightySat-3 supports Space Systems Survivability (SP06). MightySat-4 supports Advanced Structural Components (SP03) and Guidance, Navigation, and Control (SP07). MightySat-5 supports Advanced Structural Components (SP03) and Space Electronics (SE26). Specific goals that will be demonstrated include: reduce structural mass by 40%, decrease on orbit vibrations by a factor of 10, autonomous satellite navigation capable of >50m positioning uncertainly 28% efficient solar cells. 120 whrl kg rechargeable battery and reduce electronics weight by a factor of 10.

Part three is the USAF Integrated Ground Demonstration Program. This demonstrates high risk / high payoff system and payload level concepts via the ground integration of emerging technologies. This is accomplished by characterizing technology interfaces and interactions in a simulated operational environment. This technology integration capability provides the ability to evaluate advanced payload, system, and mission concepts. A specific current objective, which supports Large Precise Structures (SP05), is to demonstrate (by FY98) the feasibility of a 50% reduction in large aperture

imaging system weight. Such a capability will enable the deployment of large aperture telescopes (>2.5 meters), and enable long-dwell imaging from geosynchronous orbit. This program directly supports Air Force Space Command, Air Force Space Warfare Center, and Air Force Special Projects.

The fourth part of the demonstration program is component and subsystem technology demonstration. This program encompasses the many small flight experiments often placed in orbit through the DoD Space Test Program. The DoD Space Test Program (STP) is managed by the Space and Missile Test and Evaluation Directorate (SMC/TE); PMD guidance for STP calls for one small launch vehicle flight (Pegasus-class with satellite of less than 1000 pounds) every two years and one medium launch vehicle flight (Delta-class with satellite of 6000 to 10,000 pounds; note that ARGOS weighs roughly 6000 pounds) every four years. Experiments are selected through the Space Experiments Review Board (SERB) which meets annually to consolidate and prioritize space experiments proposed from all of the Services; experiments are ranked primarily by military relevance. STP funding is used to support experiments which don't have their own means of access to space; STP support can include providing the spacecraft bus, integrating the experiment payload, launch services, and one-year's on-orbit operations. STP also sponsors approximately 20 experiments/year on Space Shuttle flights and another two to four experiments/year on other host satellites. While these smaller experiments do not individually have significant funding or visibility, collectively they are the backbone of space vehicle S&T. An example of these small experiments is the Navy's Microelectronics and Photonics Test Bed currently in final assembly of flight hardware for launch during FY97. The objectives of the MPTB project are: (1) selection by SPOs of devices and subsystems for test; (2) perform ground–based radiation tests; (3) predict space results; (4) analyze space data and develop new radiation effects models. The MPTB experiment will space qualify devices and subsystems and demonstrate that COTS devices can operate in selected orbits. Another program is the Missile Technology Demonstration Flight. It will demonstrate Range Safety & Instrumentation to augment the use of range radar for safety and range metrics. Other examples which are currently manifested (and the flights they are on) are: Electromagnetic Propagation Experiment (STEP 4); Compact Environment Anomaly Sensor (TSX-5); Beryllium-7 Induced Radiation Experiment (Cosmos); and Polar Orbiting Geomagnetic Survey II (DMSP S-15).

3.1.3.2 Technology Development. The Space Vehicles Subarea consists of six technology efforts: Thermal Management, Structures, Survivability, GN&C, Space Power, and Astronics. Technology advances in all of these efforts are required to achieve the overall goals of this subarea. The technology efforts and their respective activities are:

- The Thermal Management effort encompasses the development of cryogenic and conventional spacecraft bus thermal management technologies required for temperatures ranging from 10° to 900° K. Technology development includes: cryocoolers that satisfy a wide variety of missions; advanced thermal integration components; very high heat transfer, capillary wicking devices; ambient temperature thermal energy storage; passive and active thermal control devices for cooling of advanced microelectronic devices; and development of deployable radiators and coatings.

- The Structures effort is being conducted to discover new ways of making lightweight, low cost, and precise structures for launch vehicles and satellites and to develop new methods to prevent vibration and structural dynamics from degrading the performance of future DoD launch vehicles and satellites. The increasing DoD need to reduce launch cost has led to a significant investment increase in launch vehicle structural component and structural control technology. Programs are exploring active control, passive damping techniques, precision deployable orbital structures, and advanced mechanisms to reduce the structural load which satellites must survive during launch. Other efforts address technology for satellites and include: concepts for lighter weight, lower cost, higher performance solar array, radiator, antenna and electronic enclosure structures; Multi-Functional Structures; and smart mechanisms for deploying and moving solar arrays and other deployable structures.
- The Survivability effort includes advanced hardening techniques, models of device response to space radiation, and methods to allow COTS devices to operate properly in the lower dose space radiation orbits.
- The GN&C effort encompasses autonomous navigation GPS technology, star trackers, and navigation instruments with the primary objective being to increase navigation and attitude determination accuracy while reducing size, power, and mass and increasing reliability.
- The Space Power effort covers the development of all required components for satellite power subsystems including power generation, energy storage, and power management and distribution. Technology development includes non-photovoltaic energy generation, investigating alternate photovoltaic material and cell designs, and increasing the solar concentration ratio of arrays. For energy storage, programs include demonstrating life, performance, and safety of NaS cells while working to develop advanced lithium-based batteries. Investigations into flywheels and other non-electrochemical storage devices have also been started. High voltage solid state relays, hybrid control patches, and integrated power chips are key power management technology approaches for the next five years.
- Sensor technology developments include large space qualified staring arrays in MWIR MCT, LWIR MCT and VLWIR Si:As for near-term applications. QWIP technology and 2-color MCT is under development for mid-term M/L/VLWIR applications. Multicolor QWIP FPAs and photon multiplier devices are in early stages of development to enable future space-based multi- or hyperspectral theater surveillance, and space-based surveillance of cold space objects against dark space backgrounds, respectively. Active sensor technologies development will use an airborne radar test to collect amplitude and phase information on clutter backgrounds representative of those expected for a SBR system to experience on a world-wide, year-round basis. This will be combined with limited data from NASA experiments and other sources to improve the validity of SBR models and simulations. Upcoming studies of non-conventional radar processing against diverse clutter environments, and automatic target recognition tests utilizing small numbers of range-resolution cells, will be leveraged to compare against conventional SBR algorithm performance. Large antenna architectures will be

developed and assessed to identify SBR sensor technologies with the highest performance payoffs.

- Space Electronics technology development focuses on increasing throughput and memory capacity; reducing weight, volume, power requirements and the cost of these systems; increasing autonomous operation of space electronics; increasing radiation hardening and survivability; and improving interoperability with other space and ground systems.
- Satellite Communications technology development focuses on GaAs, integrated optoelectronics, and laser devices to enable applications for a variety of areas including RF and optical crosslinks, and optical CDMA system area networks.
- Satellite Control technology development will investigate user friendly graphical data viewing, stored data for the life of the satellite, and extensive on-line data analysis tools; automate data in pass plan manuals, capture expert knowledge in computer based knowledge bases, and utilize model based reasoning and machine learning to resolve anomalies; support reactive, dynamic training integrated into the actual operational system with no human trainer in the loop. Trade studies will be performed to determine which functions are higher payoff for automating on-board from an O&M and satellite survivability perspective. Some on-going work in autonomous orbit control will be flight tested. Other high payoff areas will be developed further and readied for experimental flight testing.

3.1.3.3 Basic Research. Basic research to support the Space Vehicles Technology Subarea is being carried out as follows:

- **Thermal management** Basic research in this technology sub-area is focused on cryogenic technology. The objective of the cryogenic regenerator effort is to measure cryocooler regenerator performance under actual operating conditions. In addition, a numerical model for predicting regenerator performance will be developed. Numerical models do not currently exist for transient operation. The technology approach is to develop an experiment that incorporates a pulse tube cryocooler. Flow measuring and thermometer devices will be calibrated and data gathered in the 30-100 Hz range. Data will then be compared with existing models for both transient and steady state operation. Finally, an analytic model will be developed for the transient case and verified.
- **Structures** Two on-going basic research efforts are of particular interest in this area. One is developing fundamental understanding of how the different aspects of the space environment (atomic oxygen, UV, vacuum, protons, electrons, and hypervelocity debris) interact to effect space structures and structural materials. The other effort is exploring development of new mathematical control algorithms and approaches to structural control and vibration damping.
- **Space Sensors** Basic research on a Quantum Well Infrared Photon Multiplier (QWIPM) concept may lead to revolutionary passive sensor systems that are useful out to VLWIR wavelengths and operate at ambient temperatures. The QWIPM approach under study uses visible laser pumping to create a population inversion in asymmetric coupled quantum well pairs within the multiplier. With one quantum well in each pair tuned to an IR wavelength of interest, directional selection is used to discriminate and amplify the stimulated emission caused by

signal photons. The QWIPM's output burst of IR photons can then be fed into an IR detector where it will greatly exceed the ambient temperature noise background. If successful, the QWIPM would greatly simplify present and enable new earthlimb and space surveillance applications.

- **Satellite Communications** The on-going basic research "critical path" efforts are for integrated optoelectronic materials and devices for avionic and ground dynamically reconfigurable Code Division Multiple Access (CDMA) system area network; lasercom; and low voltage, low power, high speed GaAs for communications processors, modems, and light weight crosslinks and multiband transceivers.

The Space Vehicles technology subarea also relies on the results of basic research from the Sensors and Electronics, Materials/Processes, and Information Systems and Technology area Panels.

3.2 Space Propulsion

3.2.1 Warfighter Needs

Integrated High Payoff Rocket Propulsion Technology (IHPRPT). IHPRPT goals translate into payoffs to the warfighter in terms of increased warfighter capabilities. Payoffs to space launch systems include performance, cost, and reliability improvements to existing launch systems, expendable launch systems, and new reusable vehicles. The operational increases for boost and orbit transfer systems by the year 2000, 2005, and 2010 include 9%, 16%, and 22% increases in payload capability for new expendable boosters (over the 25,000 lb baseline to low-Earth orbit (LEO)). An alternative to increasing the payload on a lift vehicle would be to launch payloads on smaller, more capable vehicles to reduce the need for costly heavy-lift vehicles. The resulting launch cost reductions would equate to savings of 19%, 31%, and 42% in cost per pound to orbit. These savings are in addition to the savings seen from design and process changes. For a new reusable launch system, the payload improvements approach 71%, 127%, and 206% over the life of the vehicle by 2000, 2005, and 2010.

Spacecraft goals will result in increased warfighter payoffs through reliable critical information gathering and global communication capabilities at reduced costs. Satellites in geosynchronous orbit will be able to extend their on-orbit life up to 45%, increase repositioning capabilities by a factor of 2 to 5, or increase useful mission payload mass by 10% to 30%. This last capability can mean an ability to increase the number and/or types of transponders, potentially manifest the same payload on less expensive launch vehicles, or increase the survivability of the satellite by allowing for increased shielding material. Communication and reconnaissance satellites will be able to reposition more often and more rapidly to support the warfighter needs in local theaters of operation without significantly sacrificing satellite life. More reliable deployment and on-orbit operation throughout the life of the satellite will provide greater assurance in asset availability. Higher performance compact propulsion systems will also enable the deployment of smaller satellites into higher energy orbits. For medium-lift vehicle class geosynchronous satellites launched at a conservative rate of 6 per year, meeting the

IHPRPT goals would result in cost savings of $60 million, $130 million, and $240 million by 2000, 2005, and 2010 respectively.

3.2.2 Space Propulsion

3.2.2.1 Goals and Timeframes. The IHPRPT initiative was started in FY 1994, with primary program impacts beginning in FY 1995. The program is based on achieving the following goals (with respect to 1993 state-of-the-art baselines) for Boost and Orbit Transfer (B/OT) and Spacecraft (S/C). In space platforms the following B/OT and S/C goals exist:

2000*	B/OT** S/C:	-25% Failure Rate, +0.02 Mass Fraction (Solid), +14 sec Isp***, -15% Hardware Costs, -15% Support Costs, +30% Thrust/Wt (Liq) +10% Isp (Chem), +15% Mass Fraction, +15% Thruster Efficiency (Advanced)
2005*	B/OT** S/C:	-50% Failure Rate, +0.03 Mass Fraction (Solid), +10 sec Isp***, -25% Hardware Costs, -25% Support Costs, +60% Thrust/Wt (Liq) +15% Isp (Chem), +25% Mass Fraction, +30% Thruster Efficiency (Advanced)
2010*	B/OT** S/C:	-75% Failure Rate, +0.04 Mass Fraction (Solid), +20 sec Isp***, -35% Hardware Costs, -35% Support Costs, +100% Thrust/Wt (Liq) + 20% Isp (Chem), +35% Mass Fraction, +50% Thruster Efficiency (Advanced)
*	All percentage goals are percent change from the baseline.	
**	An additional goal for reusable propulsion systems of 20 missions between removal is also included in Boost and Orbit Transfer Propulsion	
***	Boost and Orbit Transfer Isp goal represents a combination of specific propulsion improvements at the following respective levels Cryogenic Engine: 1% (2000), 2% (2005), 3%(2010); Hydrocarbon Engine: 10% (2000),14% (2005), 17% (2010); Solid Motor (clean propellant): 7% (2000), 10% (2005), 13% (2010); Hybrid Motor: 8% (2000), 11% (2005), 15% (2010)	

3.2.2.2 Major Technical Challenges. The doubling of rocket propulsion system capability will be achieved through a combination of technology initiatives. To meet the propulsion system goals, investigations to increase the energy of propellants, increase the efficiency of combustion processes, increase the combustion chamber operating pressures, decrease the inert weight of propulsion systems, and improve the efficiency of thrust magnitude/vector control systems will be concurrently developed and consolidated. Specifically, propellant developments involve increasing performance (energy, density) and reducing costs (manufacture, storage, handling, testing) while improving the environmental acceptability. For all rocket propulsion systems, the IHPRPT initiative will provide cost reductions in a system while improving payload capability. Achieving this goal will require significant performance improvements. Future propellant requirements include improved reliability and environmental acceptability, increased safety, greater performance, longer service life, and lower life cycle costs. Propellant management devices, combustion and energy conversion devices, and control systems require innovative subcomponent and component design methods, manufacturing techniques and materials for the respective component and application area developments. The major advances required in liquid propellant combustion devices include an increase in theoretical specific impulse (Isp) by increasing chamber pressure, increases in Isp efficiency as measured by Isp actual/Isp theoretical, reductions in weight, reductions in cost, and increases in reliability (measured by decrease in part count). The

solid propulsion area consists of nozzles and the igniter. In solid propulsion, the major advances required are in increasing Isp efficiency, decreasing component weight and volume, decreasing component cost, and increasing reliability. The electric propulsion area of satellite propulsion includes the power processing components and the thrust chamber assembly, including the electrode. Major advances are needed in improving the power processing efficiency, the energy conversion efficiency, and combustion chamber life.

3.2.2.3 Related Federal and Private Sector Efforts. All DoD agencies, NASA, and industry participate in IHPRPT. Industry rocket propulsion IR&D investment for FY95 is approximately $55M. NASA FY95 investment for IHPRPT related programs for the reuseable launch vehicle is approximately $24M.

3.2.3 S&T Investment Strategy

The key to the IHPRPT process is the simultaneous achievement of the goals. Technology demonstrations conducted during each of the three phases will quantify the degree of success in reaching the goals. The technology demonstrators do not have to be a complete propulsion system demonstration. They may be individual components or a combination of components. The requirement is to prove justifiable, analytical connectivity that the compilation of the demonstrated technologies would work together as an acceptable propulsion unit. As a metric, the empirical or analytical data will be compared to baselines identified at the initiation of IHPRPT. Following demonstration, the technologies may transition economically to new propulsion systems or to improvements to current propulsion systems.

3.2.3.1 Technology Demonstrations. Technology Demonstrations for IHPRPT are divided into the three fundamental propulsion classes: (1) Boost and Orbit Transfer, (2) Spacecraft, and (3) Tactical (Tactical is book kept in conventional weapons). Each class is a separate family of demonstrations.

3.2.3.1.1 Boost and Orbit Transfer Propulsion. These demonstrations, when successful, fulfill DTO (SP10). The demonstrators for this mission application area address propulsion systems which lift payloads from ground level to orbit elevation (boost propulsion). Specific boost demonstrations will occur at the end of each IHPRPT phase. In 2000 the component improvements will feed into an integrated powerhead demonstration. In 2005, further component improvements will integrate into a high chamber pressure (4000psi) booster class demo.

3.2.3.1.2 Orbit Transfer Propulsion. These demonstrations, when successful, fulfill DTO (SP11). The demonstrations for this mission application are divided into two areas: chemical propulsion and non-chemical propulsion and address propulsion systems which move payloads from one orbit (such as low-Earth orbit (LEO)) to another orbit elevation (geosynchronous orbit (GEO)). Orbit transfer component improvements will feed into a FY00 high performance (1200psi chamber pressure) upper stage/orbit transfer demo and a FY05 high performance (1500psi chamber pressure) upper stage/orbit transfer demo.

3.2.3.1.3 Spacecraft Propulsion. These demonstrations, when successful, fulfill DTO (SP12). The technology demonstrators for this mission application include two areas: chemical propulsion and non-chemical propulsion, e.g., solar electric and solar

thermal. In all cases, these system demonstrations will be conducted at simulated altitude conditions permitting direct measurement of performance at space conditions. Solar electric demonstrations (pulsed plasma thruster and hall thruster) by 2000 and 2005 will integrate all developments for satellite stationkeeping and repositioning. Demonstrations by 2010 will demonstrate advanced solar thermal propulsion systems and advanced solar electric propulsion systems (ion thrusters) for orbit transfer missions.

3.2.3.2 Technology Development. Once the goals and payoffs have been established and confirmed as worthwhile, then the technology advancements needed to achieve the goals are determined. The propulsion technologies in BO/T and S/C are divided into the same four component technology areas. These four areas, which represent the rocket propulsion system technology improvement areas are: propellants, propellant management devices, combustion and energy conversion devices, and control systems. The efforts in the propellant area includes solid, liquid, hybrid, gels, and liner development. Propellant management efforts include work in tanks, feed systems, bladders, turbomachinery, thermal protection systems, cases, pressurization systems, and insulations. Combustion and energy conversion efforts include work in injectors, igniters, combustion chambers, nozzles, gas generators, preburners, and all components of electric and solar propulsion systems (except the propellant). Control system work includes actuator, health monitoring, thrust management, ordnance, valve, and thrust vector control system development.

The projects are technology specific as opposed to being system specific allowing for global propulsion system improvements applicable to all rocket propulsion systems. Goals within each application area address where the research and development specialists will overcome operational deficiencies and meet requirements and needs defined by the propulsion system users. Subsequently, goals are broken down into the component technology improvements needed to fulfill the achievement of the goals. These component improvements are identified and represent component area objectives that the technologists will work towards in laboratory research and development projects.

This goal/objective relationship connects the research and development labs to the user community in a way that streamlines the work done by both communities, and enables the needs of both groups to be satisfied. The result of the IHPRPT process is the fulfillment of a set of goals which integrates the technologists with the user community, and provides maximum payoffs for future space systems.

3.2.3.3 Basic Research. The Phillips Laboratory Propulsion Directorate has several basic research projects supporting development in boost, orbit transfer, and spacecraft propulsion. In boost and orbit transfer, one combustion development project (Supercritical combustion), two propellant development projects (Chemically bound excited states and Non-equilibrium flow characteristics), and three materials development projects for rocket components (Synthesis, Carbon materials research, and Material mechanics research) exist. In spacecraft propulsion, the Plasma diagnostics project supports electric propulsion development.

4. TECHNOLOGY AREA ROADMAPS AND RESOURCES

4.1 Technology Area Roadmaps

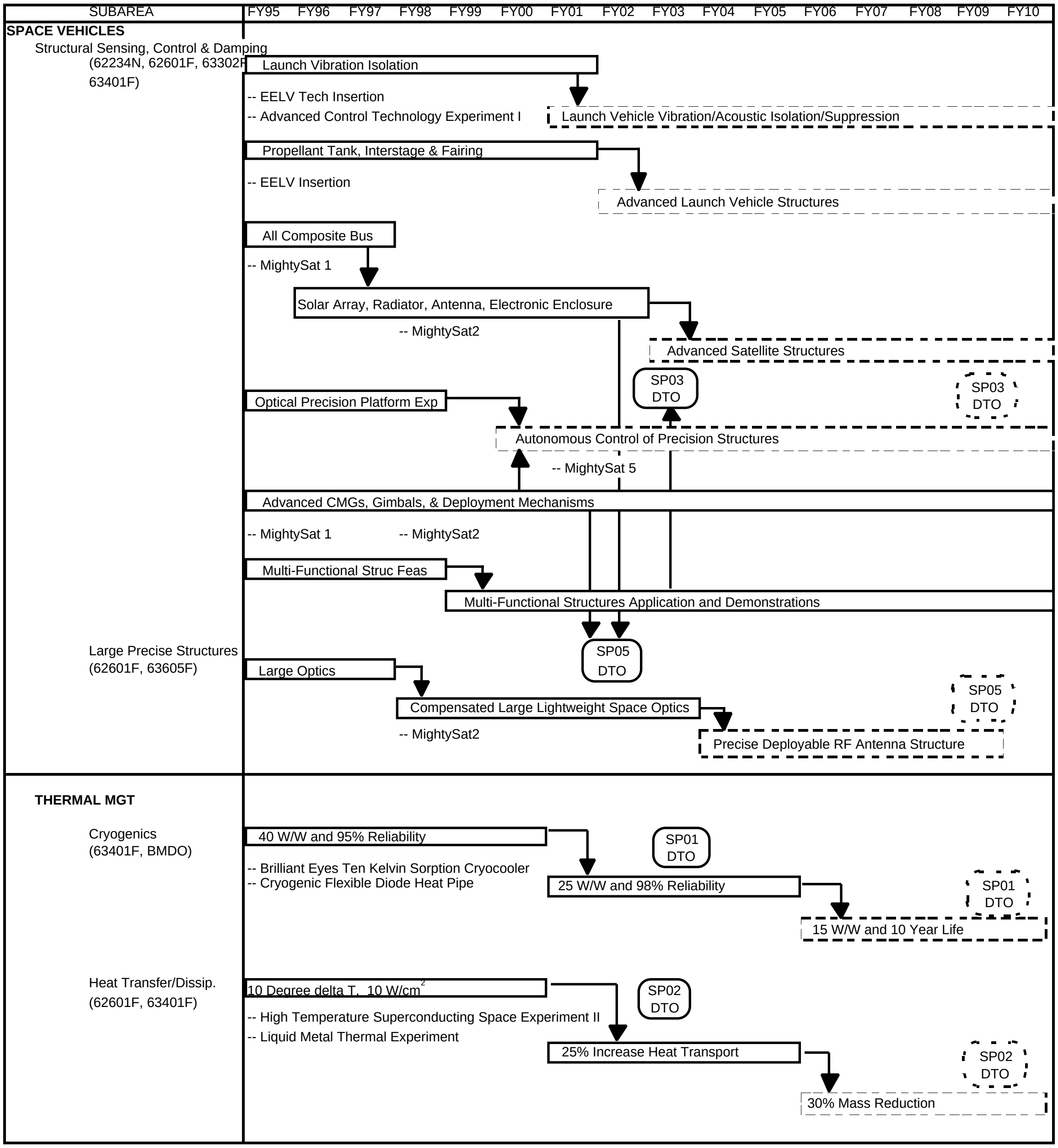


Figure VIII.3. Space Platforms Technology Roadmap

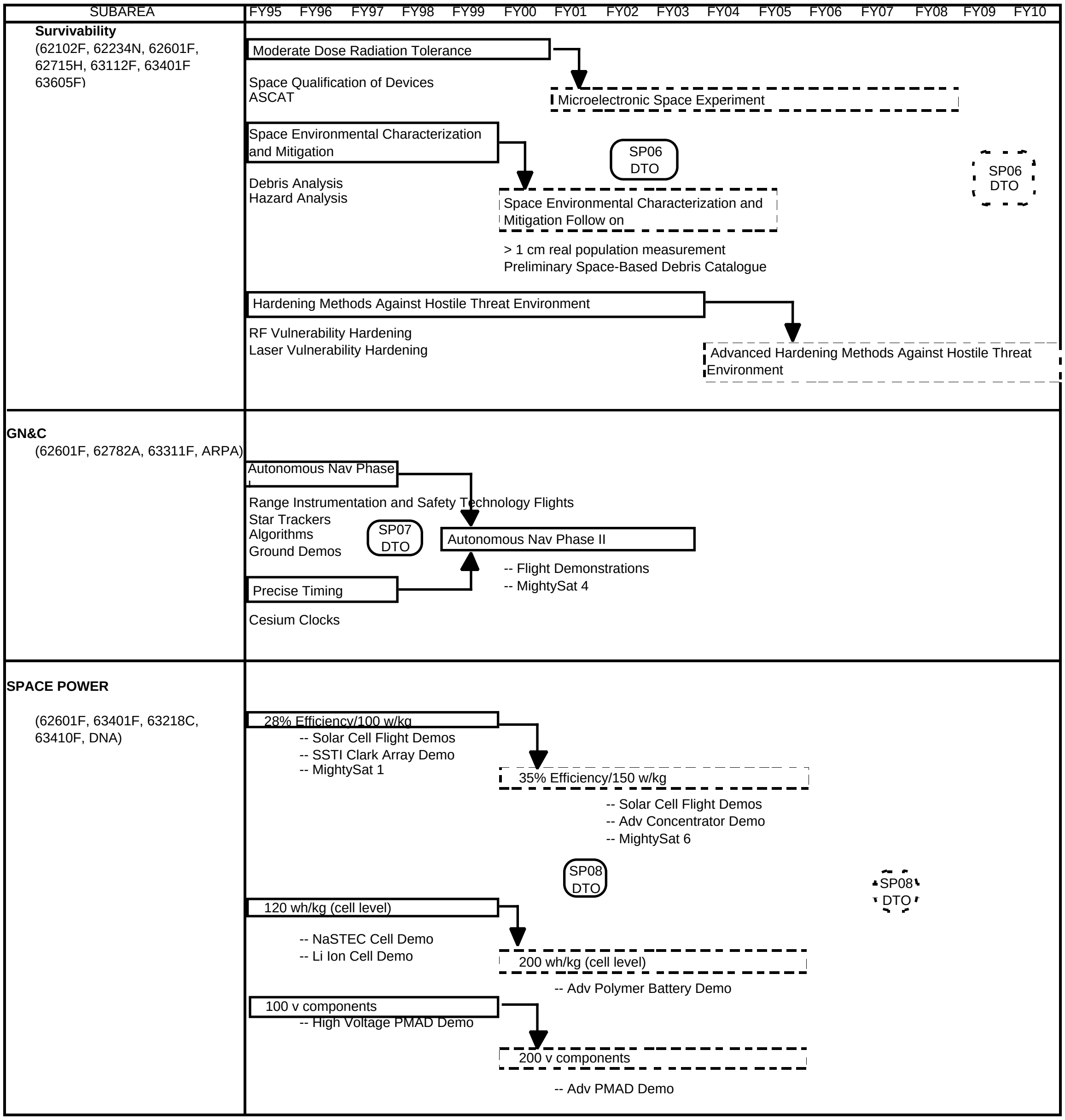


Figure VIII.3. Space Platforms Technology Roadmap (cont.)

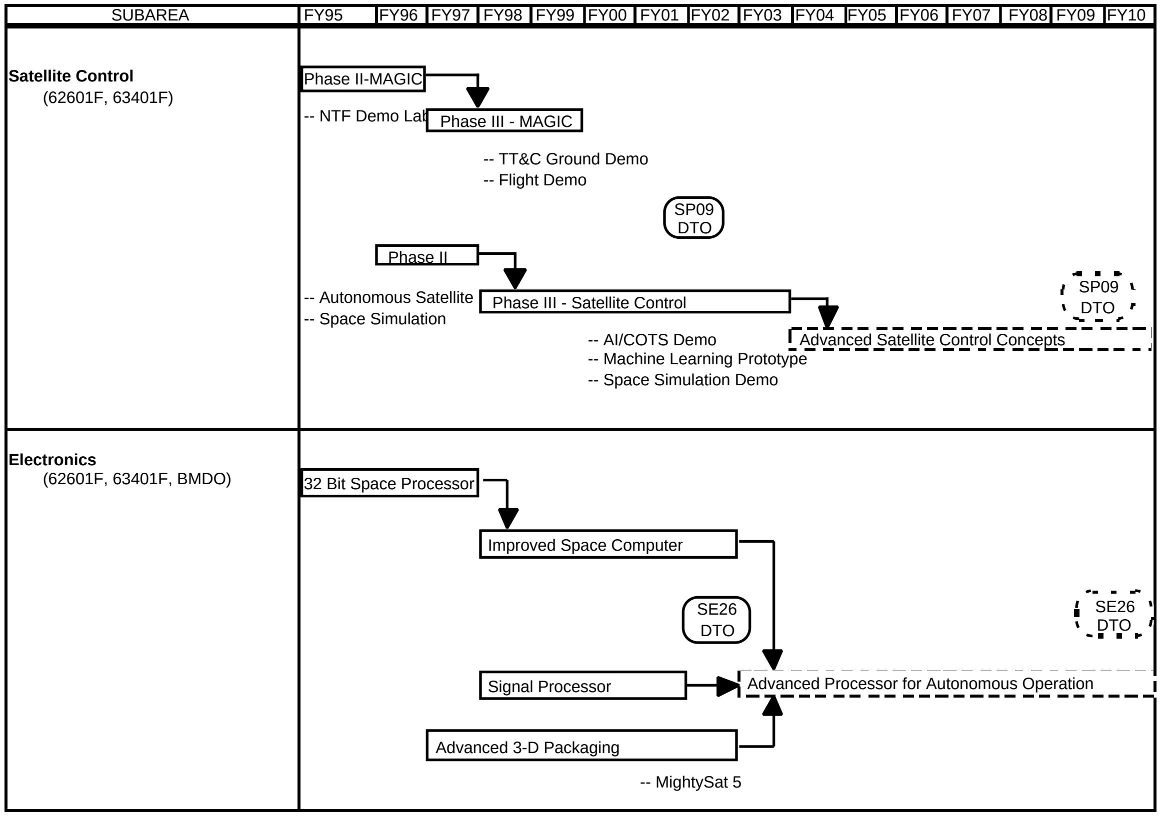


Figure VIII.3. Space Platforms Technology Roadmap (cont.)

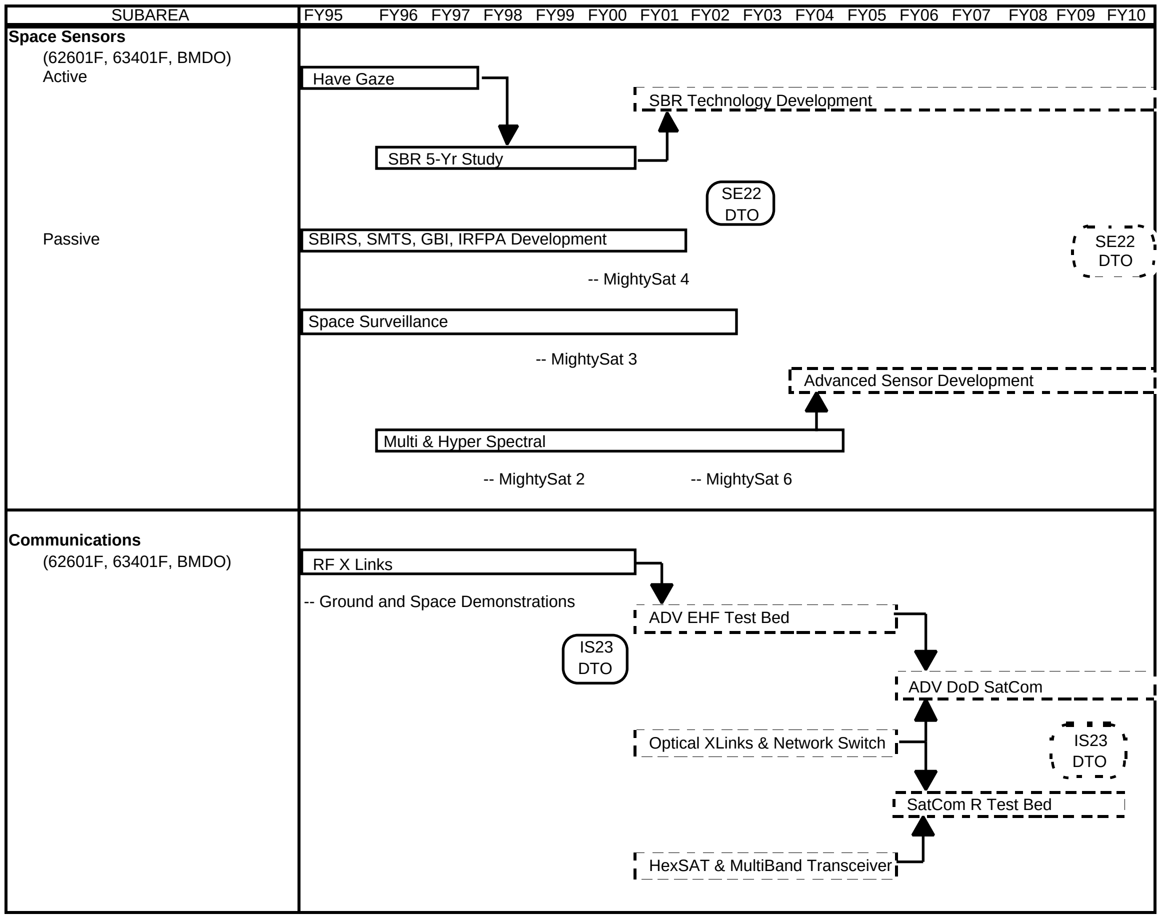


Figure VIII.3. Space Platforms Technology Roadmap (cont.)

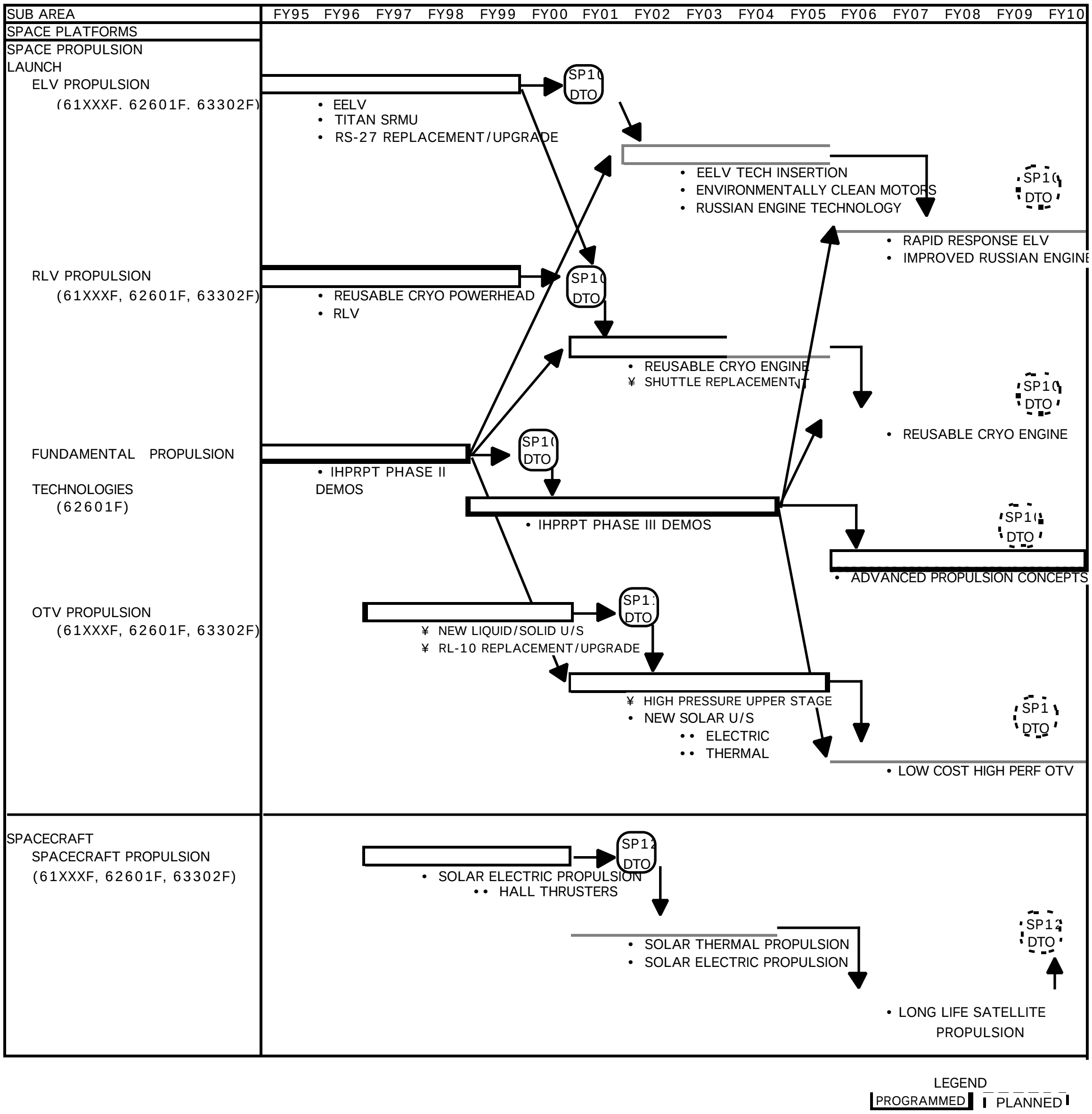


Figure VIII.3. Space Platforms Technology Roadmap (concluded)

4.2 Space Platforms Technology Area Roadmap Resources ($M)

DTOs	Program Element	$ in millions					
		FY96	FY97	FY98	FY99	FY00	FY01
SP0106FC Cryogenic Technologies	0603401F	1.0	0.8	0.8	1.8	2.4	2.9
	0603871C	4.8	11.8	11.7	11.7	11.2	4.7
	DTO Total	5.8	12.6	12.5	13.5	13.6	7.6
SP0207F Thermal Mgmt Tech	0602601F	2.6	2.3	2. 4	2.4	2.6	2.6
	DTO Total	2.6	2.3	2.4	2.4	2.6	2.6
SP0306NF Space Structure and Control	0602234N	0.4	0.4	0.4	0.4	0.4	0.4
	0602601F	5.5	5.3	5.4	5.6	6.3	6.3
	0603302F	0.6	0.6	0.6	0.6	0.6	0.6
	0603401F	1.1	1.1	1.8	2.6	3.2	4.0
	DTO Total	7.2	7.0	7.8	8.8	10.1	10.9
SP0506F Large Precise Structures	0602601F	3.5	3.8	6.4	4.3	7.2	8.3
	0603605F	--	--	1.6	2.0	2.0	2.2
	DTO Total	3.5	3.8	8.0	6.4	9.2	10.5
SP0606NFH Space Systems Survivability	0602102F	0.2	0	0	0	0	0
	0602234N	0.4	0.3	0.3	0.3	0.3	0.3
	0602601F	1.2	1.4	1.6	2.0	2.1	2.1
	0602715H	1.0	0.8	0.3	0	0	0
	0603112F	1.0	0.5	0.1	0	0	0
	0603401F	3.0	4.0	3.6	3.4	3.2	3.3
	0603605F	0.7	1.0	1.4	1.6	1.8	1.8
	DTO Total	7.5	8.0	7.4	7.4	7.4	7.5
SP0703FE Space-Based GN&C	0602601F	1.9	2.2	2.2	2.2	2.4	2.4
	0603311F	3.7	2.8	2.7	2.8	2.9	2.9
	0603226E	1.0	0	0	0	0	0
	DTO Total	6.6	5.0	4.9	5.0	5.3	5.1
SP0806FCH Space Power Technology	0602601F	3.3	3.4	3.5	5.8	5.7	4.7
	0602715H	8.5	7.0	7.1	7.1	0	0
	0603401F	4.2	4.0	4.1	4.0	4.6	4.9
	0603218C	0.1	0	0	0	0	0
	0603410F	0.2	0.3	0.9	1.1	0.9	0.6
	DTO Total	13.0	14.7	15.6	18.0	11.2	10.2
SP0901F Satellite Control	0602601F	1.1	1.3	1.3	1.3	1.5	1.5
	0603401F	1.2	2.0	2.5	3.0	3.1	3.3
	DTO Total	2.3	3.3	3.8	4.3	4.6	4.8
SP1006F Spacelift Propulsion	0602601F	20.0	18.2	15.2	15.8	17.1	21.9
	0603302F	12.6	14.0	11.8	11.8	12.8	11.4
	DTO Total	32.6	32.2	27.0	27.6	29.9	33.3
SP1106F Orbit Transfer Vehicle Propulsion	0602601F	2.8	3.1	4.9	5.5	6.0	4.9
	0603302F	1.7	0.8	2.3	4.0	3.6	5.0
	DTO Total	4.5	3.9	7.2	9.5	9.6	9.9
SP1206F Spacecraft/Satellite Propulsion	0602601F	1.2	1.0	1.4	1.5	1.6	1.0
	0603302F	--	0.1	0.1	0.3	0.3	0.4
	DTO Total	1.2	1.1	1.5	1.8	1.9	1.4

Figure VIII.4. Space Platforms Roadmap Resources
TOTALS MAY NOT AGREE DUE TO ROUNDING

SPACE PLATFORMS
ACRONYMS

ACTD	Advanced Concept Technology Demonstration
AFSCN	Air Force Satellite Control Network
AFSPC	Air Force Space Command
ARPA	Advanced Research Projects Agency
ASCAT	Advanced Spacecraft Computing and Autonomy Testbed
ATD	Advanced Technology Demonstration
AWACS	Airborne Warning and Control System
BMDO	Ballistic Missile Defense Organization
B/OT	Boost And Orbit Transfer
CDMA	Code Division Multiple Access
CHFET	Complementary Heterojunction Field Effect Transistor
COTS	Commercial Off The Shelf
CRDA	Cooperative Research and Development Agreement
DNA	Defense Nuclear Agency
DOC	Department Of Commerce
DoD	Department Of Defense
DOE	Department Of Energy
DOT	Department Of Transportation
DTAP	Defense Technology Area Plan
DTD	Digital Terrain Database
DTO	Defense Technology Objective
ECM	Electronic CounterMeasures
EHF	Extremely High Frequency
EELV	Evolved Expendable Launch Vehicles
ELV	Expendable Launch Vehicles
EMI	Electromagnetic Interference
EOS	Earth Observing System
FLEETSATCOM	Fleet Satellite Communications System
FPA	Focal Plane Array
GaAs	Gallium Arsenide
Gbps	Gigabits Per Second
GEO	Geosynchronous Earth Orbit
GN&C	Guidance, Navigation and Control
GPS	Global Positioning System
HEXSAT	Nanosatellite System Concept
Hz	Hertz
IFOG	Interferometric Fiber Optic Gyroscope
IHPRPT	Integrated High Payoff Rocket Propulsion Technology Program
IPT	Integrated Product Team
IR	InfraRed
IR&D	Independent Research and Development
ISTD	Integrated Space Technology Demonstration
JCS	Joint Chiefs of Staff
JSTARS	Joint Service Tactical Radar Surveillance
JWSTP	Joint Warfighter Science and Technology Plan
LEO	Low Earth Orbit
LOX	Liquid Oxygen
LWIR	Long Wavelength Infrared

MAGIC	Multimission Advanced Ground Intelligent Control
MAP	Mission Area Plan
Mbps	Megabits Per Second
MCT	Mercury Cadmium Telluride
MEMS	Micro Electromechanical Systems
MILSATCOM	Military Satellite Communications Architecture
MILSTAR	Military Strategic, Tactical, & Relay (Satellite)
MMIC	Monolithic Microwave Integrated
Circuits	
MPTB	Microelectronics And Photonics Test Bed
MRAM	Magneto-resistive Random Access Memory
MSLS	Multi-Service Launch System
MTBF	Mean Time Between Failures
MWIR	Medium Wave Infrared
NaS	Sodium Sulfur
NASA	National Aeronautics and Space Administration
NPOESS	National Polar-Orbiting Environmental Satellite System
NAVSPAWARS	Navy Space Warfare Center
O&M	Operation and Maintenance
O&S	Operations and Support
ONR	Office Of Naval Research
PCS	Personal Communication System
PHEMT	Pseudomorphic High Electron Mobility Transistor
PMAD	Power Management and Distribution
PMD	Program Management
	Directive
QWIP	Quantum Well Infrared Photon
QWIPM	Quantum Well Infrared Photon Multiplier
RF	Radio Frequency
RLG	Ring Laser Gyroscope
S&T	Science and Technology
SBR	Space Based Radar
SBIRS	Space Based IR System
S/C	Spacecraft
SEE	Single Event Effect
SERB	Space Experiments Review Board
SMATH	Satellite Material Hardening
SMC	Space and Missile Systems Command
SMTS	Space and Missile Tracking System
SPO	System Program Office
SOA	State of the Art
SRAM	Static Random Access Memory
SRMU	Solid Rocket Motor Unit
STIG	Space Technology Interdependency Group
STP	Space Test Program
SWIR	Short Wavelength Infrared
TAV	Transatmospheric Vehicle
TT&C	Telemetry, Tracking, and Control
USA	United States Army
USAF	United States Air Force
USASSDC	United States Army Space and Strategic Defense Command
UV	UltraViolet
VLWIR	Very Long Wave InfraRed

IX. FY 1997 DEFENSE TECHNOLOGY AREA PLAN FOR HUMAN SYSTEMS

1. INTRODUCTION

1.1 Definition/Scope

The Human Systems Technology Area brings together the physical, physiological, biological, and behavioral sciences, along with bioengineering to address all aspects of the human role in combat operations. The scope of the Human Systems research and technology programs includes nine sub-areas: Information Management & Display (IM&D), Performance Aiding (PA), Life Support (LS), Design Integration (DI), System Supportability (SS), Individual Survivability (ISV), Sustainability (SU), Manpower and Personnel (M&P), and Training (T). These sub-areas were included in three of the nineteen 1995/6 defense technology areas: Individual Survivability and Sustainability; Human Systems Interface; and, Manpower, Personnel and Training.

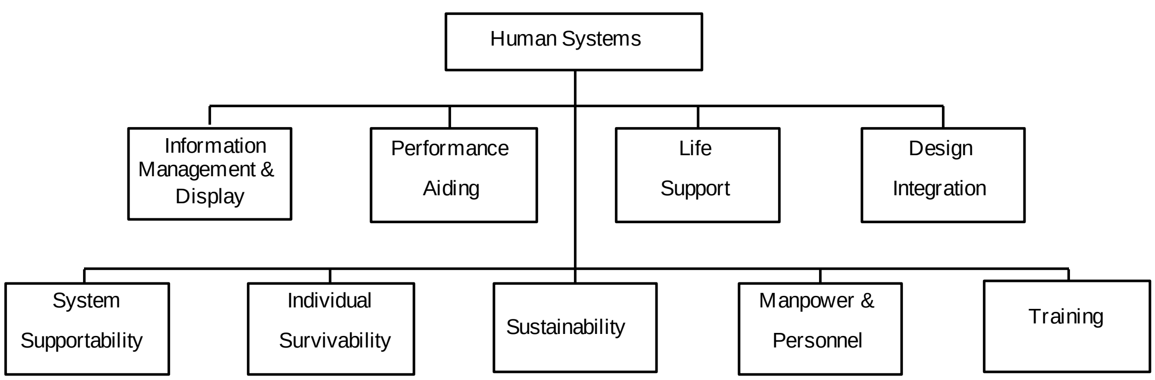


Figure IX.1. Planning Structure - Human Systems Technology Area

Major trends likely to impact the operations of the Services over the next decade include: Short-notice, long-duration strategic mission execution from a Continental United States (CONUS)-based combination of regular and reserve forces; new warfighting strategies focusing on regional threats and crisis response; highly mobile, frequently deployed, and increasingly tactical missions; increased high-technology weaponry coupled with the need for human operators to successfully cope with the information-rich characteristics of high intensity conflict; and continued importance of weapon system affordability. Human Systems technologies provide the opportunities and skills necessary to assure that personnel in all the Services are properly selected, trained, equipped, and protected to cope with these trends.

People will remain the most critical component of weapon systems. Personnel and related costs are in excess of $70B annually, with an additional $20-30B spent on training. This represents about 40 percent of the $246B FY96 defense budget. The Human Systems S&T program directly contributes to *all* Joint Staff Future Warfighting Capabilities by optimizing the use of the DoD's most critical resource in achieving those capabilities—its people. Advances in Human Systems technologies are essential for the Services to meet their global commitments in combat and peace-keeping roles.

See Resource Appendix for funding of this Defense Technology Area.

1.2 Strategic Goals

The overarching strategic goal for investment in the Human Systems Technology Area is to maintain a high degree of combat readiness and mission performance within the relatively smaller Armed Forces that are deployed across the globe. To achieve this goal, the Services must place increasing emphasis on "force multiplying" weapon systems and the retention and training of the best-qualified people. For the full range of weapon systems, the Human Systems Technology Area lies at the heart of future major gains in operability, effectiveness, availability and affordability. Over a weapon system's life-cycle the cost of the people to operate and maintain the system is significantly higher than the cost of the system's hardware. Through vigorous application of Human Systems technologies throughout the entire life cycle of current and future weapon systems, we can achieve such gains for many systems as 50-percent reductions in average crew size, 25-percent reductions in physical, perceptual and cognitive workload, 15-percent reduction in the weight of ballistic protective vests, doubling of critical decision-making accuracy and reliability, a quadrupling of overall crew member situation awareness, an 80-percent reduction in fatalities and injuries from aircrew escape, and a 50-percent reduction in total life cycle costs.

1.3 Acquisition/Warfighting Needs

Human Systems technologies collectively form the pervasive foundation upon which all weapon systems, are operated and maintained. All weapon systems including unmanned vehicles, are directly dependent on Human Systems Technologies—"there are no unmanned systems." National defense and power projection stand on the strength of the Human Systems Technology Area.

The *IM&D* sub-area supports three of the five Joint Staff future warfighting needs. Example military payoffs include a 50-percent reduction in display costs, a ten-fold increase in the probability of detection and pinpoint targeting from integrated visual and 3-D auditory displays, a 50-percent reduction in attrition during night/adverse weather operations resulting from enhanced situation awareness, a 150-percent increase in viewing area for night vision goggles, a 75-percent reduction in ground-to-ground and air-to-ground fratricide, helmet displays for rapid high off-boresight air kills and a doubling of first-pass kills. Beyond the military tradeoffs, IM&D programs produce "enabling technologies" critical to the National Information Infrastructure Initiative. Planned military transitions include helmet-mounted display integration for F-14, F-15, F/A-18, RAH-66, C2V, and the dismounted soldier.

Potential payoffs of *Performance Aiding* technologies include eliminating procedural error rates (zero tolerance) for operators of tactical workstations, reducing crisis planning by 50 percent, permitting standoff target sorting and selection, reducing load carry requirements by 25 percent, increasing by 10 times the human ability to lift-and-carry, and improving situation assessment by a factor of three in operating mobile armor, tactical aircraft, carrier battle groups and command centers. The *Performance Aiding* technologies are targeted for assisting operators of new systems, such as M1A2 Plus, RAH-66, F-22, JAST variants, teleoperated HMMWV, and Unmanned Scout Vehicle, and for upgrades to existing systems, such as AH-64, F/A-18E/F, and AEGIS Shipboard Combat Systems.

The major payoff from *Life Support* technologies is to expand the operational environment under which aircrew can perform, thus increasing both mission effectiveness and crew safety, including lives saved and minimizing combat and non-combat operational casualties. Sustaining the warfighters through *Life Support* technologies means "winning the fight" during combat while conserving assets. Typical near-term applications are planned for F/A-18E/F, F-22, JPATS, and aircraft that may emerge from the JAST program. Foreign technology (i.e., Russian K-36 ejection seat) will also be exploited.

Example *Design Integration* payoffs include quantifying the system performance baseline at acquisition Milestone I, reducing by 50 percent the time needed to develop and evaluate the crew system, reducing by 75 percent design-induced operator errors, and reducing by a factor of ten the need for redesign at the test and evaluation stage.

System Supportability costs account for most of the total weapon system life cycle costs. For aircraft, support costs exceed 80 percent of total life cycle costs. New information systems technology offers enormous payoffs both for rapid resupply in warfighting and for curtailing the cost for high lifetime systems. Examples of payoffs are improved trouble-shooting tools to allow field maintenance technicians to reduce diagnostic errors by 15 percent during repair. Successful demonstration of the Integrated Maintenance Information System (IMIS) on F-16 aircraft resulted in adoption of the technology by the F-22 and JSTARS SPOs. Improved methods for identifying and eliminating design-related supportability problems during acquisition and design increase weapon system availability by 10 percent during operational use. Weapon system transition targets include land vehicles such as the Advanced Field Artillery System, new air vehicles from the JAST program, and upgrades to the entire range of land combat vehicles and aircraft.

Individual Survivability technology developments are high-payoff investments that support many of the Joint Chiefs of Staff mission capability areas. Capabilities provided by the 21st Century Land Warrior (21CLW) ATD will include integrated position/navigation global positioning system (GPS) and inertial navigation; enhanced night maneuverability; and modular, lightweight, and interoperable components tailorable to mission requirements. The Army/ARPA program for helmet-mounted displays will provide an integrated headgear system (for mounted and dismounted crewmen) to increase situational awareness and magnify the ability to fulfill demanding operational needs.

In the *Sustainability* sub-area, performance enhancing ration components will increase the warfighter's mental acuity, physical performance, and ability to deal with

battlefield stress. New thermal and non-thermal preservation and active packaging technologies will result in the capability to provide high quality rations for optimizing nutrient consumption. Inflatable airbeam structures provide rapidly deployable shelters in forward areas for quickly establishing a presence to include command and control (C2) centers. Initiatives in precision airdrop technology will provide capabilities critical to both rapid worldwide insertion of CONUS-based initial forces and just-in-time (JIT) resupply of rapidly moving forces.

Payoffs from the *Manpower and Personnel* sub-area include increased personnel and unit readiness, minimized personnel dislocations costly to personnel readiness, reduced training costs and time, reduced attrition from training (including flying training), and improved mission effectiveness through higher performance levels of military members. The operational commanders will see improved mission performance through more efficient allocation of personnel to duties with requirements that match individual strengths and reduced manpower requirements through better alignment of job structures to accomplish the mission.

The payoffs of the *Training* sub-area include new strategies and technologies which improve training effectiveness and efficiency. Intelligent, computer-aided training technologies will reduce training development time and costs, improve deployability of training, and improve performance by trainees. Research on how to train tactical decision making potentially will increase decision-making accuracy by 40 percent and timeliness by 30 percent. In other arenas, air combat units will be able to deploy with complete ground-based training systems, to realistically rehearse missions anywhere in a timely manner, and to fulfill all training requirements, not just those that their flying hour programs allow.

2. DEFENSE TECHNOLOGY OBJECTIVES (DTOs)

HS 01 05 A	21st Century Land Warrior
HS 02 00 F	Advanced Aircrew Escape
HS 03 06 AF	Aircrew Distributed Mission Training
HS 04 01 FN	Cognitive Engineering for Information Dominance
HS 05 06 F	Crew Station Integration Demonstrations
HS 06 06 AF	Crew System Engineering Design Tools
HS 07 06 N	Dev. of Adv. Embedded Trng. Concepts for Shipboard Systems
HS 08 06 A	Force XXI Training Strategies
HS 09 02 AF	Helmet-Mounted Sensory Ensemble
HS 10 11 F	Integrated Tech. Info. to Improve Maint. Perf. and Operations
HS 11 11 F	Log. Tech. for Flexible Contingency Deployments and Operations
HS 12 52 FN	Night Vision Goggle Technologies

HS 13 02 A	Precision Offset, High Glide Aerial Del. of Vehicle Munitions & Equip.
HS 14 05 A	Rotorcraft Pilot's Associate
HS 15 05 A	Small Arms Protection for the Individual Combatant
HS 16 03 A	Thermal Signature Reduction for the Individual Combatant
HS 17 06 A	Warfighter Systems Modeling (WSM)
HS 18 06 FN	Weapon System Decision Support

3. TECHNOLOGY DESCRIPTIONS

3.1 Information Management & Display (IM&D)

3.1.1 Warfighter Needs

The nature of today's information-rich battlespace environment demands that at every level of command, the warfighter is provided or can select the right information at the right time. IM&D technologies provide the warfighter cost-effective information management displays that optimize the decision-making process. Within the IM&D program, helmet display technology transitions are underway via demonstrations in F-14, F-15, F/A-18 and RAH-66 aircraft. Immersive displays and 3-D displays are on the horizon. These technologies will transition to new-build, forward-fit and retrofit vehicle programs, including F-22, RAH-66, F/A-18E/F, JSF, M1A1, M2A1, M3A1, AH-1G, AH-1S, AH-64, OH-58, OH-6A, AWACS, UH-1N, UH-60A, C-141, P-3, land vehicle night-driving systems, AEGIS Combat System, Open Combat Direction System, CVN76, Advanced Tomahawk weapon control, ship self-defense system, next generation attack submarine, CINCPAC Disaster Relief Anchor Desk, Joint Maritime Command Information System, Land Attack Targeting Project, and advanced sensor technology programs.

3.1.2 Information Management & Display Overview

3.1.2.1 Goals and Timeframes. The IM&D goal is to maximize information throughput from sensors and processors to the warfighters via displays. By FY97, high resolution, wide field-of-view, night vision devices will expand the performance envelopes and decrease accident rates for helicopters, transports, ground troops, and special operations personnel. By FY98, ejection-safe helmet display systems will link to missiles for multiple, high off-boresight kills in fighters and helicopters. By FY01, 3-D audio displays will expand the crew's situation awareness, survivability, and effectiveness. By FY03, advanced data fusion/processing will provide near real-time information for battlefield awareness and rapid replanning. Large color graphic displays will support 3-D volumetric views, while 3-D audio, speech recognition, and color helmet displays will assist in threat warning and targeting for aircraft, ground forces, and ships. By FY10, immersive virtual reality devices will be available for combat crew

stations, including those for remotely-piloted vehicles. Today's patchwork of display and control panels will be replaced with mixed-modal voice, eye, brain, and touch interfaces.

3.1.2.2 Major Technical Challenges. New ways to represent and visualize data without clutter are essential. Too many information sources threaten to overwhelm the human capacity to monitor, broadcast data, and query data sources. The challenge is to tailor information delivery to match the senses of vision and audition. For effective human performance on the digitized battlefield, systems must convey the right information, at the right time, and in the right context. Toward this end, we are beginning to understand how to exploit human capabilities within virtual environments. Technology demonstrations for day/night helmet displays are showing the operational utility of linking the human to weapon control in fighters and helicopters, and are exploiting miniature color components, daytime-compatible image brightness, and advanced optics while retaining form factor and reducing weight.

3.1.2.3 Related Federal and Private Sector Efforts. Related efforts are underway at several research universities, NASA, FAA, and at 10 major aerospace companies via IR&D. Additionally, the Department of Veterans Affairs is working on neural network recognition of hand gestures and the neurological substrate of auditory localization. International efforts also include a Nunn Program sponsorship involving the Air Force and the French federal government for S&T research in virtual crew system technologies. There is a pending Nunn Program endeavor with the United Kingdom.

3.1.3 S&T Investment Strategy

3.1.3.1 Technology Demonstrations. IM&D demonstrations are confirming the operational potential of helmet displays for multi-use day/night operations. The Air Force and Navy are completing the congressionally-initiated demonstration of helmet-mounted tracker/display (HMT/D) equipment in fighters, using new Navy missile seekers to expand the field-of-regard. This includes aircraft-specific HMT/D integration on F-15, F-14 and F/A-18. The Visually-Coupled Acquisition & Targeting System (VCATS) ATD is demonstrating technology for the Joint Helmet Mounted Cueing System by rapid line-of-sight cueing of the missile seeker to the target, and by standardizing integration of HMT/Ds into cockpits and simulators. The Helmet Mounted Sight-Plus (HMS+) ATD adds functionality through color miniature components. The Panoramic Night Vision Goggle ATD expands the potential for night operations.

3.1.3.2 Technology Development. A data visualization effort confronts the data overload problem for cross-service applications spanning command centers, vehicle crew members, and individual soldiers. It exploits computer graphics, voice control and sound cues, better display symbology, and stereo 3-D displays. Aural and visual interface research develops information management criteria for advanced component technology to maximize the information throughput. It focuses on uses of aural and visual cues to present spatial information for integrated flight, weapon, and sensor operations across the range of aircraft, ships, command centers, helicopters, tanks, and for the individual soldier. The immersive interface work exploits component technologies from other IM&D efforts to develop an advanced, multi-user, immersive environment consisting of integrated surround-screen, helmet-display, 3-D auditory input, and tactile force-feedback.

3.1.3.3 Basic Research. Scientists conducting basic research in IM&D are discovering design principles both for individual displays and full user interfaces. On-going research focuses on gaining a deep understanding of human perceptual, cognitive, and motor-control processing within complex task environments.

3.2 Performance Aiding (PA)

3.2.1 Warfighter Needs

Performance Aiding extends the performance envelope for operational and support personnel by fostering effective real-time operations in hostile environments. It contributes to the Joint Staff goal of maintaining near-perfect real-time knowledge of the enemy and communicating that to all forces in near real-time. Near real-time knowledge of the enemy enables "faster-than-real-time" maneuver dominance strategies. Specific payoffs are: eliminate procedural error rates (zero tolerance) for operators of tactical workstations; reduce crisis planning time by 50 percent; permit standoff target sorting and selection outside threat weapon ranges; achieve orders of magnitude reduction in risk through telerobotics; reduce human load carry requirements by 25 percent through task and equipment redesign; increase by 10 times the human ability to lift-and-carry; improve the speed and accuracy of situation assessment by a factor of three in operating mobile armor, tactical aircraft, carrier battle groups and command centers; and improve weapon system operational capabilities through computer-supported combat decision aids. Transition opportunities to improve operability, combat performance and supportability are targeted to new systems such as M1A2 Plus, RAH-66, JSF, F-22, the Smart Ship, Advanced Combat Direction System, Surface Combatant 21, and to upgrades to existing systems, such as AH-64, F-15E, F/A-18E/F, F-14 Quickstrike, and the AEGIS.

3.2.2 Performance Aiding Overview

3.2.2.1 Goals and Timeframes. Performance Aiding technology will enable the nation's armed forces to operate well beyond their normal mental and physical capabilities, and enhance system performance in stressful, hazardous, time-constrained, and remote environments. By FY97, an intelligent multi-platform integration of tactical information in aircraft cockpits as well as teleoperated HMMWV and USV will be demonstrated. By FY98, crewmember associate technologies for reconnaissance-attack rotorcraft will be demonstrated and transitioned to the Army's advanced rotorcraft and main battle tank design programs. Night-driving sensors for the UGV will be demonstrated in operational settings. Models of tactical situation assessment and decision-making for real-time operations will be formulated, embedded in decision support systems, and evaluated by FY99. Principles and decision support system prototypes for collaborative decision-making and distributed information processing will be demonstrated by FY01. Models and architectures will be developed and evaluated by FY05 to significantly augment cognitive, perceptual, and physical task performance over a range of stressful military environments (undersea, amphibious, battlefield, battleforce, aerospace). The models and architectures will be usable across the Services and defense agencies and beyond to include private sector spin-offs (e.g., heavy construction, search and rescue, fire fighting, mining, and oil exploration).

3.2.2.2 Major Technical Challenges. A primary challenge is to represent the human interaction with emerging technologies, from physical to cognitive to psychological perspectives, with intelligent aids in forms that are usable for engineering design processes. Meeting the challenge involves developing accurate models of biodynamics, ergonomics, human cognition, decision-making, and stress, merging them with weapon systems models and realistic mission scenarios. Additional challenges include accelerating technology maturation for very high speed, real-time mission planning and decision support systems, developing decision support tools to monitor and counter the adverse effects of high operational stress and maintain high sustained operator performance levels, and developing computerized, collaborative, intelligent support systems to enhance individual physical and decision-making performance on the battlefield and in the battle group. Since target acquisition is a key to successful military operations, performance aids must be developed which, when combined with active and passive sensors, can provide information on texture, shape, and color effects on weapons' signatures. These aids will improve detection and identification of objects in underwater and aerospace environments. Rotorcraft, in particular, often must operate in high threat scenarios for which the integration of advanced mission equipment functions and data presents the major challenge. Performance Aiding technologies are critical for gaining real-time internal situation awareness through data fusion and cognitive decision aids.

3.2.2.3 Related Federal and Private Sector Efforts. Programs sponsored by the FAA, NASA, DOT, and DOE apply Performance Aiding technology to civil domains (civil aviation, ground transport, and nuclear power generation). Related industry IR&D projects are underway and cooperative R&D agreements with industry have been negotiated.

3.2.3 S&T Investment Strategy

3.2.3.1 Technology Demonstrations. The Rotorcraft Pilot's Associate (RPA) ATD is the Services' premier Performance Aiding demonstration program. The RPA's objective is to apply artificial intelligence and advanced computing and decision support technologies to the integration and management of next-generation mission equipment and digital battlefield information to enhance the lethality, survivability, and mission effectiveness of combat helicopters. When fully developed, the Rotorcraft Pilot's Associate will assist reconnaissance-attack helicopter crew members in performing mission functions that will improve overall mission effectiveness and survivability.

3.2.3.2 Technology Development. Intelligent aiding and decision support technology produces computational techniques and quantitative models of physical processes and information processing for use by military planners and strategic/tactical decision makers. Supervisory control and teleoperation technology adapts integrated sensors, platform control techniques, and dexterous manipulation devices to remotely-controlled robotic systems. Physical aiding technology can amplify/extend an individual's physical strength and endurance, for more effective performance in sustained military operations. Distributed collaboration technology is the key to effective joint mission planning, situation assessment, and mission monitoring by command staffs/teams that are physically separated and geographically distributed.

3.2.3.3 Basic Research. There are two different paths of fundamental research in Performance Aiding. One is exploring all issues associated with integrating a human

with electronic agents. The second path is investigating novel (explicit and implicit) user-control channels as well as theoretical paradigms for human control systems.

3.3 Life Support (LS)

3.3.1 Warfighter Needs

Life Support technologies enable warfighters to perform their missions and survive in nominal and emergency operational environments. This research serves the Joint Staff warfighting need to engage regional forces promptly in decisive combat on a global basis. To protect crewmembers during emergency escape from aircraft, advanced ejection seat technology can reduce by 50 percent the "out-of-envelope" fatalities and injuries caused by high speed ejections. New G-protection technology can enable pilots to match the aircraft's structural envelope up to +12 Gz, providing a significant tactical advantage in air combat. Emerging threats from laser and CB weapons require defensive measures. Self-generating breathing gas technology is needed to meet the large-flow demands of transport aircrews, and to eliminate the need to purchase and handle liquid oxygen (LOX). This technology will cut logistical costs and eliminate injury risks associated with LOX.

Transition opportunities include: (1) aircraft escape technology for F/A-18E/F, F-22, JPATS, and JSF, (2) advanced hybrid oxygen technology for transport aircraft and field hospitals, (3) aircrew environmental cooling, (4) laser eye protection, and (5) seating components such as advanced restraints, energy absorbers, inertia reels and seat cushions. These opportunities can transition directly to the fighting forces.

3.3.2 Life Support Overview

3.3.2.1 Goals and Timeframes. The subarea goal is to demonstrate technology resulting in affordable Life Support systems that allow warfighters to perform effectively while fully exploiting the weapon system's performance capabilities in the face of environmental hazards and enemy threats. By FY97, demonstrate safe escape from combat aircraft at speeds above 700 KEAS, which is more than a hundred knots over today's limit, test an advanced Aircrew Personal Environmental Cooling System, and determine the effects of decompression sickness and positive pressure breathing at high altitude. By FY98, quantify aircrew capabilities up to +12Gz and demonstrate that fighter pilots can endure combat maneuvers for 30 percent longer without significant increases in fatigue. By FY99, reduce the weight, volume, and cost of crew oxygen generation by 20 percent, increase oxygen recovery rate by 50 percent, and demonstrate a proof-of-concept large-flow oxygen system for large aircraft, that offers savings exceeding $1 billion. By FY00, flight test a modular Advanced Integrated Life Support System to improve cockpit mobility while reducing injuries and fatalities in air operations.

3.3.2.2 Major Technical Challenges. The basic challenges are to protect warfighters and enable them to operate effectively, while circumventing environmental hazards (heat, cold, smoke, vibration, acceleration, motion and altitude), and other threats (battlefield lasers and chemical-biological agents). The challenges for personal protection include fatigue and loss-of-consciousness under sustained G-forces, design

criteria for aircraft seats, restraints, and helmets under vibration, acceleration and impact forces, operating at cabin altitudes above 30,000 feet, eliminating aircraft modifications for eye and respiratory protection, increasing oxygen recovery levels with on-board nitrogen generation, and providing self-generating medical-grade oxygen. For escape/crash safety, the technical challenges include: understanding the response and injury mechanisms from windblast; developing means for safe aircrew escape at high-speed and adverse aircraft attitudes; developing analytical models for human response to ejection forces; accommodating females and small males during emergency escape; identifying limits on mass and center-of-gravity for head-mounted equipment; developing instrumented manikins for impact/sled tests; and understanding the windblast and burn hazards at high Mach temperatures.

3.3.2.3 Related Federal and Private Sector Efforts. FAA, NHTSA, and NASA have related Life Support programs. Industry IR&D at major aerospace companies add to the technology base as do small business innovative research (SBIR) contracts. Additionally, the Services participate in NATO's Advisory Group for Aerospace R&D (AGARD) and its various Working Parties. For example, the Foreign Comparative Test (FCT) Program includes examination of the K-36 ejection seat.

3.3.3 S&T Investment Strategy

3.3.3.1 Technology Demonstrations. This subarea has two major demonstrations: Crew Protection for Advanced Escape Systems and Advanced Integrated Life Support Systems. The Escape Systems demonstration is validating the technologies required for a safe escape envelope matching the entire flight regime of combat aircraft with the future flying population. This includes safe escape both from high speed and from low altitude/adverse aircraft attitudes. The work includes proof-of-concept equipment, high-speed sled testing and flight testing. The Life Support demonstration is developing integrated, modular life support equipment technology to improve operability and reduce stress, while expanding both the effective protection and the operational envelope. Demonstrations of flight-qualified subsystems provide operational users an opportunity to "fine tune" requirements before engineering development.

3.3.3.2 Technology Development. Personal protection technologies offers protective equipment solutions to counteract the physical forces and threats present in normal and emergency operations. Specifically included in these technologies are crew station equipment and structures, environmental control systems, human physiology and biomedical effects, and the human susceptibility to mechanical forces. The S&T work includes breathing systems, in-flight monitors, and comprehensive protection (altitude, sustained acceleration, whole-body vibration, ballistic, bioacoustics, eye and NBC protection). Crew evacuation technology offers life sustaining equipment for patient care during air transportation. Escape/crash safety technology provides for the emergency egress of personnel from the weapon system and protection during survivable crashes. It addresses escape from tactical aircraft using open ejection seats, capsules or hybrid systems, and methods to optimize occupant survivability during a crash and egress after a crash. Survival and rescue technologies focus on providing personnel the means to survive until rescued following an operational or training mishap. The technologies include protective clothing, flotation devices, survival equipment, and rescue devices.

3.3.3.3 Basic Research. Life Support basic research investigates the brain biochemistry of laboratory animals before and during G-induced loss of consciousness (G-LOC) episodes.

3.4 Design Integration (DI)

3.4.1 Warfighter Needs

All systems have a human interface. Optimal performance requires integration of the human's capabilities and limitations in the design of the system. Ultimately, the design integration of weapon systems links to all five of the Joint Staff Future Joint Warfighting Capabilities, and the man-machine interface is central to effective design integration. Near-term linkages apply to three of the five: maintain near real-time knowledge of the enemy, engage regional forces in combat on a global basis, and support operations at the lower end of the warfighting scale with minimum casualties and collateral damage.

Crew-centered design processes are tailorable for new acquisitions and upgrades and are targeted for applications in all the Services' air, land and sea operations. Transition opportunities include land vehicles such as M1A2 Plus, air vehicles including JSF as well as upgrades to the entire range of fixed-wing and rotary-wing aircraft, and to Navy surface and subsurface platforms. Human Systems design and test tools are targeted for JPATS and JSF, plus upgrades to F-15, F/A-18E/F, F-22, B-1, B-2, Commanche (AH-66) and Apache Longbow (AH-64D). Additional users for assessing soldier-system performance, effectiveness, usability and acceptability include the DCSPER, ARIEM, DWHRP, 21 CLW TLD, NRDEC, ARDEC, and SOF.

3.4.2 Design Integration Overview

3.4.2.1 Goals and Timeframes. Design Integration goals include: developing a national technology base in human performance modeling and assessment; designing tools for physical accommodation; devising methods for human error assessment; and validating methods and tools for crew station design and test. All design integration tools are set in the context of weapon system engineering. By FY97, the Services' test agencies will be able to plan and perform evaluations of man-machine systems on a common basis using common support tools. An electronic database offering quantified and diagnostic data will be distributed to designers and a crew-centered cockpit design process will be verified. By FY98, valid metrics will be established for assessing human decision-making, operator workload, and situation awareness. By FY00, human performance metrics will correlate to weapon system effectiveness. By FY02, analytic and simulation tools to design for operability will be proven, including an operator integration testbed that enables designers to accommodate the needs of warfighters as they intend to fight. By FY05, a fully functional electronic crew associate will be available to support platform operations.

3.4.2.2 Major Technical Challenges. Improved sensors, advanced communications, increased threats, and more powerful propulsion, data processing, as well as munitions, continue to increase the complexity of warfighter missions and the weapon systems employed to accomplish the missions. A massive amount of human

performance data has been collected over the years. However, it either is not available to the Design Integration community or is difficult to locate and interpret. Consequently, integration is performed late in the design process and evaluations rely on costly physical prototypes. Industry crew station designers lack the analysis and design tools comparable to those available in other disciplines. Models and measures to design for effective human performance are needed, but must link to the CAD/CAE tools used in vehicle engineering. Largely due to the extent of human variability, quantitatively linking the human interface to system effectiveness is considerably more difficult than establishing such criteria for physical systems.

3.4.2.3 Related Federal and Private Sector Efforts. These efforts include: FAA investments in design integration for air traffic control; NASA investments in design integration for Space Shuttle improvements, civil transports, general aviation, and future space operations; and IR&D programs underway in the aerospace sector of the domestic economy.

3.4.3 S&T Investment Strategy

3.4.3.1 Technology Demonstrations. The principal subarea demonstration showcases crew-centered design technologies, which focus on using design integration tools in tandem with a tailorable crew-centered engineering process for military acquisition agencies and industry. Crew centered design technologies include a model process for vehicle crew station design integration. The technologies also include computer-based tools for crew system analysis, design, simulation, and flight test evaluation.

3.4.3.2 Technology Development. The design tools effort provides design technology building blocks for crew station designs across Service applications. It develops the underlying engineering processes, design aids, guidelines, software systems, data bases, man-machine system models, and standards which allow man-machine models to be integrated with conventional design principles. Performance metrics develops tools and analysis procedures to evaluate the man-machine interfaces along dimensions of operator workload, vigilance and situation awareness, and logically extends to measures of system effectiveness. Crew station integration develops and evaluates mission-unique, crew station concepts for anticipated operational requirements and integrates the technology base from the other Human Systems man-machine interface sub-areas in the context of specific platforms, missions, tactics, and operating procedures.

3.4.3.3 Basic Research. Basic research in human performance, particularly in cognitive processes, will provide important input to human performance models and design tools.

3.5 System Supportability (SS)

3.5.1 Warfighter Needs

Affordability is a key challenge facing national defense leaders. Containing the support cost by trimming the logistics tail is a key to future warfighting capability. This

subarea contributes to all five Joint Staff future warfighting needs by providing technology to streamline the human component of system supportability. Support costs exceed 80 percent of total life cycle costs of aircraft systems. Many aircraft remain in the inventory longer than planned, so configuration control can be a 40+ year challenge. Identifying ways to eliminate supportability problems during the acquisition phase of a weapon system will increase weapon system availability by 10 percent. Improved trouble-shooting tools will reduce diagnostic and repair errors by 15 percent, resulting in faster maintenance and improved combat readiness for land and air systems. Accurately estimating supportability requirements can reduce the personnel-related costs by 25 percent over the weapon system life cycle. Transition targets include the Oklahoma City Air Logistics Center, the Air Combat Command, the Air Force Materiel Command, and the Army's Automated Information System program managers. Weapon system transition targets include land vehicles such as the Advanced Field Artillery System, new air vehicles such as the JSF, and upgrades to existing air and land vehicles.

3.5.2 System Supportability Overview

3.5.2.1 Goals and Timeframes. The overall goals of the System Supportability subarea are to improve weapon system affordability and availability and to reduce support costs. Emphasis is placed on improving the weapon system support infrastructure and developing human supportability estimation methods and tools. By FY00, these methods and tools will improve by 40 percent the performance of logistics planning personnel, field personnel, and depot personnel in combat and peacetime operations. An Aircraft Battle Damage Assessment and Repair aid which significantly reduces turn-around time, and a large-scale depot maintenance information system for system repair will be demonstrated by FY00. In addition, a validated suite of tools will enable accurate estimation of Manpower, Personnel, and Training (MPT) requirements for weapon systems along with mechanisms for reducing MPT requirements early in design. This will save 25 percent in MPT costs, reduce design-induced operator and maintainer errors by 25 percent, and reduce by 25 percent the number of human-related design changes identified by test and evaluation.

3.5.2.2 Major Technical Challenges. Maintenance depot technicians require the means to directly inter-communicate to all electronic maintenance systems, to obtain all necessary information on the depot line, and to view large drawings and schematics on a small portable computer screen. Unit level deployment planners lack reliable logistics planning systems, including a central deployment knowledge base of site maps, site surveys, lessons learned, and videographic site information. As DoD moves away from a paper-intensive design and logistics environment, new challenges arise. Among these are how data is stored and managed, how it is integrated across multiple, distributed platforms, how it is shared among diverse disciplines, how legacy data is incorporated, how the human is integrated in the new environment, how organizations and their processes exploit automation, and what metrics are used to measure success. In today's budget-constrained operations, systems must be designed to be operated and maintained by affordable manpower who have affordable training, a definited challenge when estimating human resources in early system formulation.

3.5.2.3 Related Federal and Private Sector Efforts. There are no known comparable efforts in the federal sector. DoD has unique supportability requirements

including, improved maintenance capabilities in combat environments, during rapid deployments, and for varied contingency missions. Commercial industries (e.g., Boeing and Northwest Airlines) and the Federal Aviation Administration are leveraging DoD system supportability technologies to improve maintenance and support of commercial airliners. The Nuclear Regulatory Commission is adapting electronic technical manual technologies.

3.5.3 S&T Investment Strategy

3.5.3.1 Technology Demonstrations. The Flexible Deployment and Maintenance Performance demonstration embraces enhanced deployability, maintenance and logistics functions. Work in this subarea includes technology for more reliable aircraft support equipment, improved cargo handling, more effective information aids for battle damage/repair, and more efficient computer planning tools for contingency deployments. The supportability in acquisition/design demonstration is a series of related ATDs aimed at significantly reducing the life cycle cost of weapon systems by inserting advanced technology into high leverage points in the defense logistics infrastructure.

3.5.3.2 Technology Development. Operational logistics deals with field-oriented supportability, especially maintenance performance and logistics planning. Acquisition logistics includes the design technology for producibility and supportability associated with man-machine interfaces. MPT and human performance requirements estimation concentrates on folding MPT requirements into the materiel design process, particularly for new systems. These efforts target the next generation of information systems needed to support our weapon systems, interrelate maintenance requirements analysis and design trade-offs, apply technical information systems providing integrated electronic technical data to the maintenance/repair depots, and introduce supportability requirements estimation methods to incorporate personnel-related considerations into the acquisition process.

3.5.3.3 Basic Research. Basic research in human performance will be leveraged in the development of human supportability estimation methods and tools.

3.6 Individual Survivability (ISV)

3.6.1 Warfighter Needs

Technology developments are high-payoff investments that support these Joint Warfighting Capabilities: Military Operations in Urban Terrain, Combat Identification, Chemical/Biological Warfare Detection, Joint Readiness, and Joint Countermine. Capabilities provided by the 21st Century Land Warrior (21CLW) will be technology upgrades and linkage to the digitized command and control network with near real-time battlefield intelligence, load-bearing equipment, and survival technology. Capabilities such as accurate, automated target hand-off, unexposed firing/viewing, and signature suppression/control ensure a precision strike capability at the individual combatant level.

Dual-use applications include high-performance fibers for ballistic/blast protection for law enforcement agencies. Flame and thermal resistant fibers have strong

dual-use in firefighting applications, race car driving, and aircraft piloting. Microclimate conditioning (MCC) applications will benefit industrial workers, law enforcement personnel, firefighters, and medical patients.

3.6.2 Individual Survivability Overview

3.6.2.1 Goals and Timeframes. By FY98, demonstrate an advanced material system for protection against combined fragmentation and small arms threats; demonstrate, in a robust squad exercise, the integration of risk mitigating technology upgrades to 21 CLW's dismounted Force XXI Soldier System; demonstrate modeling, simulation, and analytic tools to quantify and maximize the viability of individual combatant concepts and equipment; and demonstrate an electrochemically driven heat pump with fuel cell power and sodium borohydride-based hydrogen generator, as an MCC system driver. By FY03, demonstrate an improved prototype for second generation multiple ballistic threat protection; demonstrate combat uniform systems that reduce the soldier's thermal signature to blend with background levels; demonstrate frequency-agile laser eye protection that incorporates non-linear optical materials in a goggle configuration; and demonstrate advanced firefighter/damage control ensemble fabrics and concepts.

3.6.2.2 Major Technical Challenges. The overall challenge of the Individual Survivability subarea is to develop advanced materials while simultaneously reducing the weight and bulk associated with increased multi-functional protection. The countersurveillance challenge is to provide passive protection against advanced sensors without degrading current protection. Integrated protective material challenges are: develop uniforms that provide protection against multiple threats, are cost effective, and do not impose a heat stress penalty; provide lightweight, low power, portable, MCC systems; and develop test procedures correlating with material performance under field conditions. Warrior performance challenges include modular performance augmenting components integrated within the fighting system and visual/auditory displays in helmet systems for individual combatants. Laser eye protection challenges include development of thin films with high third-order nonlinear components. The warfighter systems modeling challenge is to collect and implement high-fidelity, valid models of human response to support the demonstration of the individual combatant system components in a synthetic environment. The 21CLW challenge is to orchestrate and transition developments in microelectronics and signal processing, sensors, individual power sources, flat panel displays, and materials.

3.6.2.3 Related Federal and Private Sector Efforts. The Defense Logistics Agency (DLA) is working to move clothing production toward an apparel-on-demand capability. NASA and FEMA are working with DoD on advanced firefighter clothing technology. The Navy is active in the NFPA firefighting standards-setting arena. DoD and the DoJ have initiated a MOU for ballistic protective technologies. Active NATO working groups include warfighter standardization and modernization efforts. There is strong participation in TTCP for textile materials, human factors, and soldier modernization. DEAs exist with France, Germany, Korea, Sweden, and the Netherlands. The Army and NASA are collaborating on heated handwear and MCC design/operating parameters. DoE is also currently conducting thin film and ballistic protective materials research.

3.6.3 S&T Investment Strategy

3.6.3.1 Technology Demonstrations. By FY98, the 21 CLW program will demonstrate the integration of risk mitigating technology upgrades and secure early user feedback on proposed technology insertions to Land Warrior. The ballistic protection program will demonstrate by FY98 an advanced material system for protection against combined fragmentation and small arms threats. By FY98, MCC will demonstrate an electrochemically-driven heat pump, integrated with a fuel cell power supply and sodium borohydride based hydrogen generator, as an MCC system driver. Warfighter systems modeling technology will demonstrate modeling, simulation, and analytic tools quantifying and maximizing the viability/capability of warrior concepts/equipment by FY98. The fit-adjustable fireboot program will demonstrate an adjustable fit system for firefighter boots (three sizes fit all) by FY97.

3.6.3.2 Technology Development. Technology advancements and demonstrations above are contingent upon breakthroughs in these areas: system integration; protection against flechettes, small arms, fragmentation, and blast threats from mines and bursting munitions; textile materials for camouflage; fibers, fabrics, clothing, and individual equipment systems for protection in all climates and environments; protection against lasers, microwaves, and nuclear/thermal threats; integrated application of anthropometry, biomechanics, and biophysics.

3.6.3.3 Basic Research. Basic research for ballistics protection includes an understanding of polymer functionality through synthesis, characterization, and processing. Biotechnological approaches to new ballistic materials involve mimicking the processes found in nature to produce new ceramics. Basic research in support of laser eye protection involves understanding the non-linear response of materials and using biotechnological methods (enzyme-driven polymer synthesis) for development of new non-linear optical materials.

3.7 Sustainability (SU)

3.7.1 Warfighter Needs

Sustainability technology developments support the Joint Warfighting Capabilities of: Military Operations in Urban Terrain, Precision Force, Joint Readiness, and Real-time Logistics Control. Performance enhancing ration components will increase the warfighter's mental acuity, physical performance, and ability to deal with battlefield stress. Non-thermal preservation and active packaging technologies will result in the capability to provide high quality rations. Breakthroughs in diesel fuel combustion, heat-driven refrigeration, and thermal fluid heat transfer will enable morale-boosting, cook-prepared meals. Advanced airdrop technology will permit rapid worldwide insertion of CONUS-based forces, allow for battlefield resupply, and furnish a low-cost airdrop capability for OOTW. Inflatable airbeam structures enable rapidly deployable shelters in forward areas.

Dual-use applications exist for disaster and humanitarian relief, sports, recreational activities, forest fire fighting, space vehicle recovery systems, and special dietary concerns.

3.7.2 Sustainability Overview

3.7.2.1 Goals and Timeframes. By FY98, demonstrate: modulated nutrient release during periods of high energy demand; operational flexibility of mobility-enhancing ration components; and optimize airbeam technology for transition to the forward area surgical shelter. By FY03, demonstrate rapidly deployable field feeding system technology; demonstrate a 5,000- to 10,000-pound high glide airdrop system; validate nonthermal preservation techniques; and optimize the incorporation of complex carbohydrates for modulated energy release.

3.7.2.2 Major Technical Challenges. A significant sustainability challenge is that the natural complexity of food systems affects the chemical, physical, and nutritional characteristics leading to undesirable changes which are further compounded by lengthy, uncontrolled storage. Ration challenges are to ensure that food variations do not limit product safety, packaging innovations which provide a high degree of protection are developed with minimized product interaction, and, there is continuous improvement of ration quality/variety. Performance challenges include development of rations and supplements with optimized nutritional value and stability which deliver neurotransmitter precursors to tissue sites and modulate the release of energy-rich constituents. Equipment challenges include decreasing size and weight while increasing field feeding capability and developing reliable, efficient, non-electric cooking and refrigerating appliances that do not require electric power. Airdrop challenges include modeling of the transient parachute opening processes and developing a reliable deployment process for a semi-rigid wing technology. Finally, shelter airbeam technology challenges involve manufacturing of advanced three-dimensional textiles as well as defining optimized uses and orientations of high-strength fibers.

3.7.2.3 Related Federal and Private Sector Efforts. By participating in the Advanced Food Technology Consortia with Rutgers University, the government leverages over $4M in basic research with a $40,000 investment. DEAs exist with Germany, Israel, France, Korea, Norway, Sweden, Canada, and Great Britain. There is an MOU with USDA to insure mutually supportive and non-duplicative programs. The Research and Development Associates for Military Food and Packaging Systems, Inc. holds semiannual forums specifically to coordinate and address military subsistence needs.

Army and NASA are collaborating to add a landing parachute to the Space Shuttle Orbiter and the use of GPADS technology as the recovery system for the NASA X-35 recovery vehicle. The Army is also working with Draper Labs and NASA to develop a guidance, navigation, and control package that can be used to guide parafoil systems. The Army is working with industry to adapt a proprietary hang glider semi-rigid wing to a cargo pod that can be extracted from a C-130 aircraft. Pressurized flexible composite technology has further applications including inflatable ejection seat stabilizers, deployable high glide wings, and mobile floating platform.

3.7.3 S&T Investment Strategy

3.7.3.1 Technology Demonstrations. By FY98, demonstrate: thermal processes to ensure product quality, microbiological safety, and prevention of oxidation/product degradation through in-package additives; the capability to modulate nutrient release during periods of high energy demand; thermal fluid heat transfer

technology in a prototype compact efficient field kitchen and the ability to cleanly burn diesel fuel in a catalytic vaporizing burner; and, optimized airbeam technology suitable for the forward area surgical shelter. By FY99, demonstrate novel combination preservation aids, and demonstrate an increase in payload capability for high-glide, precision-guided delivery and soft-landing technologies that eliminate personnel landing injuries and reduce cargo rigging/derigging times by 50 percent. By FY00, demonstrate a 15-20 percent increase in nutrient bioavailability of reformulated ration components. By FY03, demonstrate a rapidly deployable field feeding system prototype based on advances in diesel combustion, heat transfer, and refrigeration.

3.7.3.2 Technology Development. The technology advancements and demonstrations listed in Section 3.7.3.1. are contingent upon breakthroughs in: food science, physical chemistry, nutrition, behavioral sciences, chemical engineering, packaging, preservation, stabilization, and processing; combustion, thermodynamics, heat transfer, thermoelectric power generation, automatic control and refrigeration technologies; fibers, fabrics, stress/strain properties, coatings and concepts for airbeam structures and textile-based shelters; designs and concepts for parachutes/gliding wings and cargo/personnel airdrop systems and theoretical/computational prediction and experimental determination of decelerator behavior and performance.

3.7.3.3 Basic Research. Preservation and stabilization research includes determining the key structural features in protein-carbohydrate reactions that lead to formation of chemical markers and assessing the thermal denaturation of proteins as a function of processing. Performance enhancement and nutrition research will demonstrate oral delivery of microencapsulated bioactive nutrients to targeted susceptible tissues. Airdrop technology efforts will focus on computational techniques for the prediction of the opening phase of the parachute.

3.8 Manpower and Personnel (M&P)

3.8.1 Warfighter Needs

Manpower and Personnel technologies have a direct force-multiplying effect on personnel and unit readiness in all critical elements of warfighting capability. M&P technologies will improve the Services' capabilities to select and classify the highest quality applicants (more than 160,000 per year). Personnel quality translates into reduced attrition, reduced time in skill training, and more capability on the battlefield. Decision support systems to be developed in 3-5 years target a 5-10 percent cost avoidance in support requirements through better system design and more accurate projection of life-cycle costs. New generations of aptitude tests coupled with more sophisticated assignment systems will save 15 percent in the time required to achieve warfighting skill proficiency. M&P technologies are critical in defining future requirements and ensuring maximum mission capability as the services assume new roles and missions.

Military M&P technologies transition to applications solving critical national problems. Advances in testing technologies benefit industrial firms that hire at the unskilled entry level. Advanced techniques will also be available for executive

development and optimal career pathing; motivating and supporting a workforce of increasing diversity; and dealing with organizational downsizing.

3.8.2 Manpower and Personnel Overview

3.8.2.1 Goals and Timeframes. The following goals will be achieved through advances in force management and modeling (FM&M), improved selection and classification (S&C) methods, and new human resource development (HRD) technologies. By FY97, a training seat allocation system will reduce student wait time by 15 percent. By FY99, there will be: a 10-percent increase in reliability for measuring leader capabilities; an ability to prescribe a set of recruitment, promotion, and retention policies needed over a succession of years to achieve future force levels; and, more effective strategies for manning units, ships and squadrons to minimize the turnover of critical personnel during key readiness periods. A comprehensive system designed to match individuals to jobs and career paths, across services, that best fit their interests, temperaments, and capabilities will be available by FY01. By FY02, moving costs will be reduced by $60M per year due to better recruiting and selection techniques. New tests and assignment algorithms will result in a 20-percent decrease in training time by FY03.

3.8.2.2 Major Technical Challenges. Technical improvements are needed in statistical forecasting, mathematical optimization, information science, and artificial intelligence. Other technical challenges include needed advances in job analysis that identifies mental requirements, self-report and self-inventory measures that resist falsification, more objective measures of mission performance, and, Battle Command performance effectiveness baseline measures.

3.8.2.3 Related Federal and Private Sector Efforts. This subarea cooperates fully with investments by the Federal Aviation Agency, the Departments of Labor and Commerce, and the Office of Personnel Management. Joint research efforts are on-going with the U.S. Military Academy, the U.S. Army War College, and the Industrial College of the Armed Forces. Cooperative Research and Development Agreements are in place with Howard University, the University of the District of Columbia, and the University of Maryland.

3.8.3 S&T Investment Strategy

3.8.3.1 Technology Demonstrations. The Use of Multi-Component Organizations in Peacekeeping Operations will help determine the feasibility of deploying composite units of reserve and active service members for peacekeeping missions. Developing Battle Command expertise will demonstrate, in realistic field and laboratory exercises, tools and techniques to improve command and staff performance on critical battle command tasks. Intelligent Job Advertising and Selection System will demonstrate decreased PCS moving costs, while increasing fleet readiness and the number of assignments meeting personnel preferences. The Manpower, Personnel, and Training in Acquisition Decision Support System will ensure that MPT issues are properly and cost-effectively integrated into new and upgraded weapons systems.

3.8.3.2 Technology Development. Technology advances are needed in all the following areas to achieve M&P goals. An improved model of human abilities must be developed to efficiently and optimally assign personnel to jobs. Measures of human

abilities must be expanded to incorporate personality characteristics such as motivation, temperament, and values. Validation of newly-developed test batteries must continue, in order to determine the predictability and utility of these new instruments. New job-structuring methods must be developed to provide improved personnel assignment and manpower modeling. New methods for optimizing and simulating crewing alternatives must be developed along with improved assignment technologies. Rapid changes in the scope and nature of military operations require new leadership assessment devices and leader development technologies.

3.8.3.3 Basic Research. Efforts are underway to develop a better understanding of the motivational, situational, and personality characteristics of leaders, and how their skills are developed within various organizational structures. A goal of the program is to develop a conceptual model of leader-team performance. Also, a conceptual model is under development to relate the millions of possible assignment alternatives to readiness. If mathematical formulation is feasible, faster and more efficient algorithms will facilitate solving these problems.

3.9 Training (T)

3.9.1 Warfighter Needs

Contemporary training readiness challenges include preparing for a diverse set of contingency operations while maintaining the capability to conduct major engagements. Added to this complexity of training management are pressures to reduce the training budgets for flying hours, steaming days and operating tempo. Training technologies are being developed to reduce the cost and increase the effectiveness of current training, and to re-engineer future training processes. New aircrew training methods will soon be in use that will improve mission performance and reduce aircraft safety incidents by at least 25 percent. Through use of advanced, simulator-based mission rehearsal systems, combat units will be able to conduct training that is currently too hazardous or unaffordable. Low cost, high fidelity cockpit simulators that are deployable and networkable will be available in many aviation squadrons within 3-5 years for "on-demand" training. Night vision device training systems will increase warfighters night operational capability by 40 percent. Future training developers will produce valid, high-quality instruction modules in one-tenth the time nominally taken today. Warfighters will conduct highly realistic joint/coalition training in integrated virtual, live and constructive synthetic environments, increasing combat capability by 30 percent, while saving at least 60 percent in current training budgets.

Many military training technologies have dual uses and will transition across the services, other government agencies, industry, and the educational community. The training and simulation principles obtained from crew-coordination and stress research can be applied to civilian air traffic control and hospital emergency room contexts. Intelligent tutors in physics and medicine are projected for transition in the near term. Foreign language tutors will meet the need for rapid skill train-up and sustainment and embody a clear application to civilian education and business training needs. Low-cost, high-fidelity, cockpit training simulations have the potential to significantly lower the cost of commercial flight training.

3.9.2 Training Overview

3.9.2.1 Goals and Timeframes. The overarching goal of the Training subarea is to develop the technologies which will improve the delivery of the right training in an affordable manner, when and where it is needed, to DoD personnel worldwide. By FY97, research on how to train tactical decision making will improve decision making performance by 40 percent. Prototype distributed interactive simulation (DIS)-based, structured training programs will increase the readiness of National Guard units by 50 percent. By FY01, authoring tools will be developed that reduce training development time and costs by 90 percent. By FY01, combined arms training strategies for the digitized battlefield will increase training efficiency by 50 percent (number of tasks trained in the same amount of time). The training vision for FY01 and beyond is to produce seamless simulation environments that allow actual combat systems, manned simulators, constructive war games, and other simulations to exercise on virtual battlefields. Many of the Training subarea goals are geared toward developing the training technologies to ensure realization of this vision.

3.9.2.2 Major Technical Challenges. Technical approaches are needed to overcome the following challenges. The effects of DIS on training readiness cannot be assessed independently of the training programs that provide a context for the assessment. Visual systems are needed that can provide cost-effective, realistic imagery to warriors, and visual cues in virtual battlefields used for training. Realistic training, practice, and timely feedback need to be provided to widely dispersed small units. Military instruction needs to be managed and modified more efficiently to respond to demands for “just-in-time” training.

3.9.2.3 Related Federal and Private Sector Efforts. Tactical decision making training research is related to decision making research at NASA Ames and to the FAA's aeronautical decision making and air traffic control training research. Joint research is underway with Lockheed-Martin and medical equipment providers, to improve medical training using VE technology. Efforts to model dismounted soldiers in VE are underway at the Naval Postgraduate School and the University of Pennsylvania. The Defense Nuclear Agency is developing instructional methods and technologies to sustain nuclear weapons expertise. Their system will incorporate classroom, distance learning, and computer-based instruction, which will feature real-time accident response exercises and simulation scenarios.

3.9.3 S&T Investment Strategy

3.9.3.1 Technology Demonstrations. Simulation in Training for Advanced Readiness will develop and demonstrate training technologies to raise by 50 percent the training readiness levels in National Guard units by FY97. The Training Impact Decision System will develop and demonstrate a decision support system to conduct “what if” analyses of proposed changes in personnel, budget, and training resources. Interactive Multisensor Analysis Training (IMAT) will develop new training techniques for very complex warfare tasks (training for future threats of littoral warfare, where on-the-job training is dangerous and not feasible). The Deployable Night Vision Device (NVD) Training System will be developed to train warfighters in NVD use.

3.9.3.2 Technology Development. Simulation-based training technologies need to be developed which realistically train warfighters in combat/support tasks that would

be otherwise too costly, very difficult or unsafe to train them using actual equipment. The instructional capabilities of DIS systems need to be maximized and assessed to effectively deliver distributed training to individuals and units. Performance measures and feedback techniques need to be developed to ensure that synthetic training environments will be used effectively for estimating and maintaining training readiness. Cost-effective training strategies must be provided to maintain combat readiness via seamless combinations of virtual, constructive, and live simulation components. The efficiency of developing and delivering individual training must be improved to reduce the cost of military classroom instruction by 25 percent. Prototype intelligent tutoring systems in technically challenging military occupations need to be developed for skill acquisition and sustainment.

3.9.3.3 Basic Research. Efforts are underway to better understand the interactions among task characteristics, individual differences, feedback, and training practices that affect the development of cognitive or mental models and contribute to information processing, learning and retention. Also, basic research efforts will investigate new algorithms for improving speech recognition systems to support weapons system trainers, the role of spatial abilities in the training effectiveness of distributed interactive simulations, and, the training impacts of individualized automated instruction.

4. TECHNOLOGY AREA ROADMAPS AND RESOURCES

4.1 Technology Area Roadmaps

Figure IX.2. focuses on the linkages and key relationships associated with the corresponding DTOs funded through the Future Years Defense Plan (FYDP).

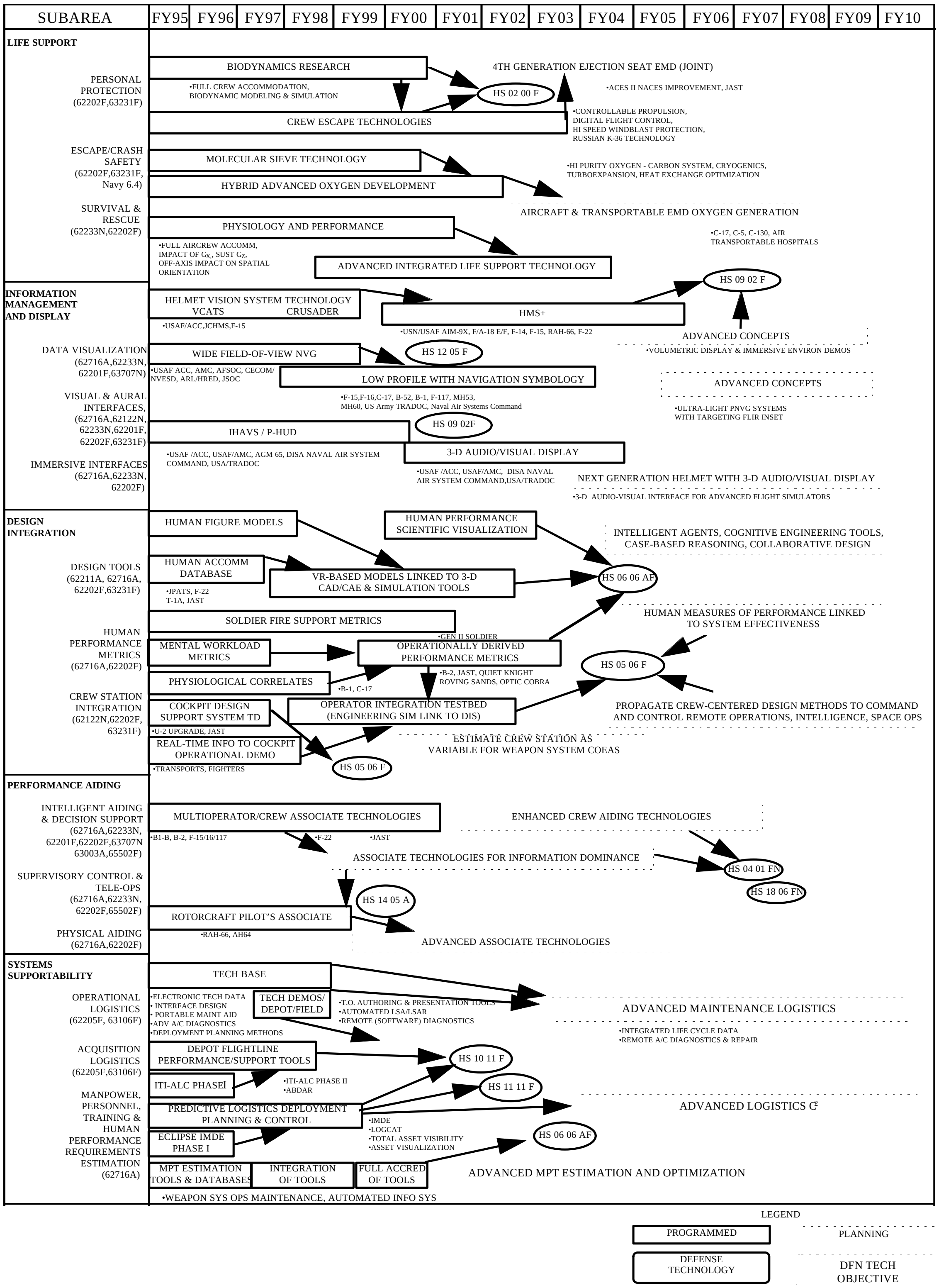


Figure IX.2. Human Systems Technology Roadmap

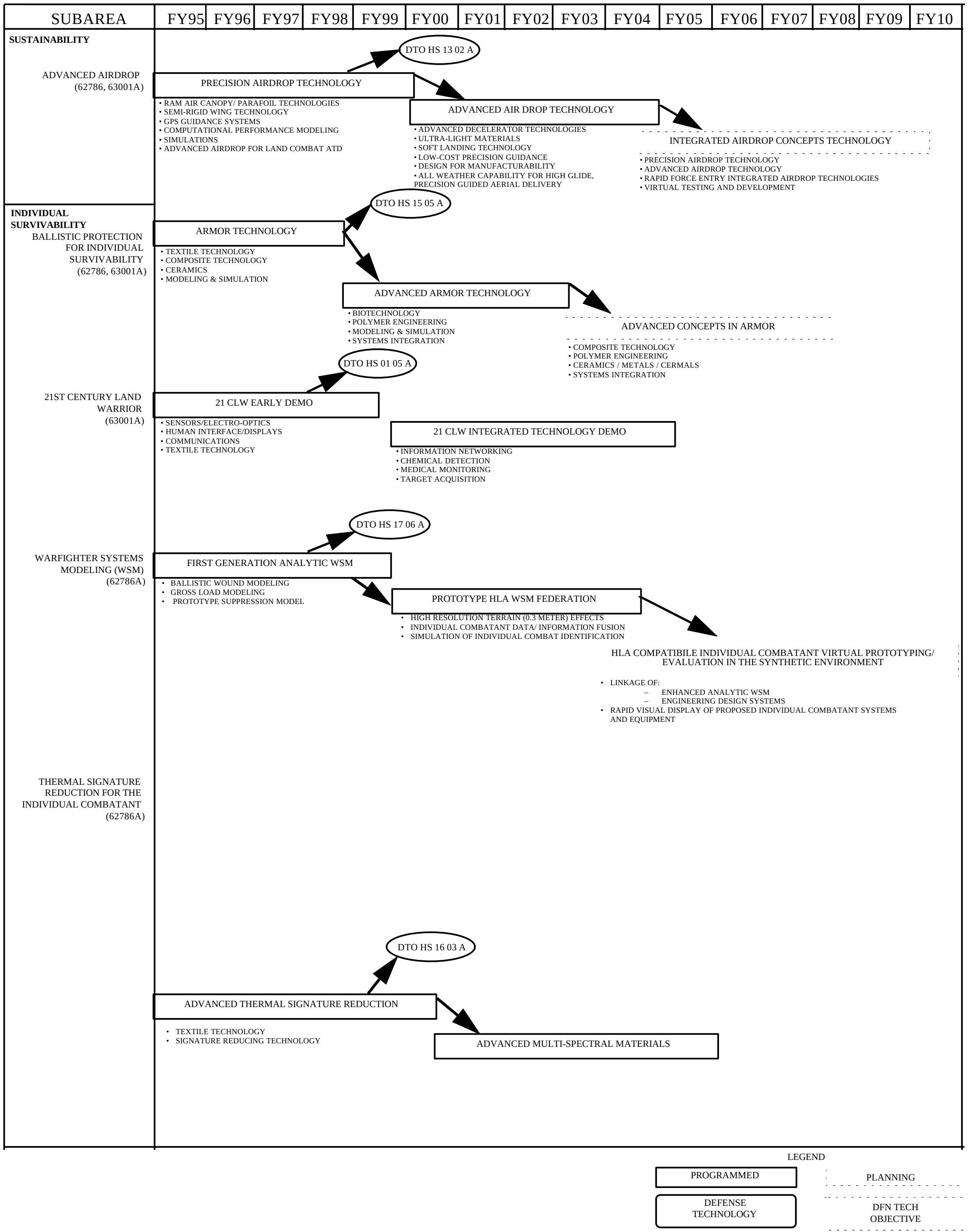


Figure IX.2. Human Systems Technology Roadmap (cont.)

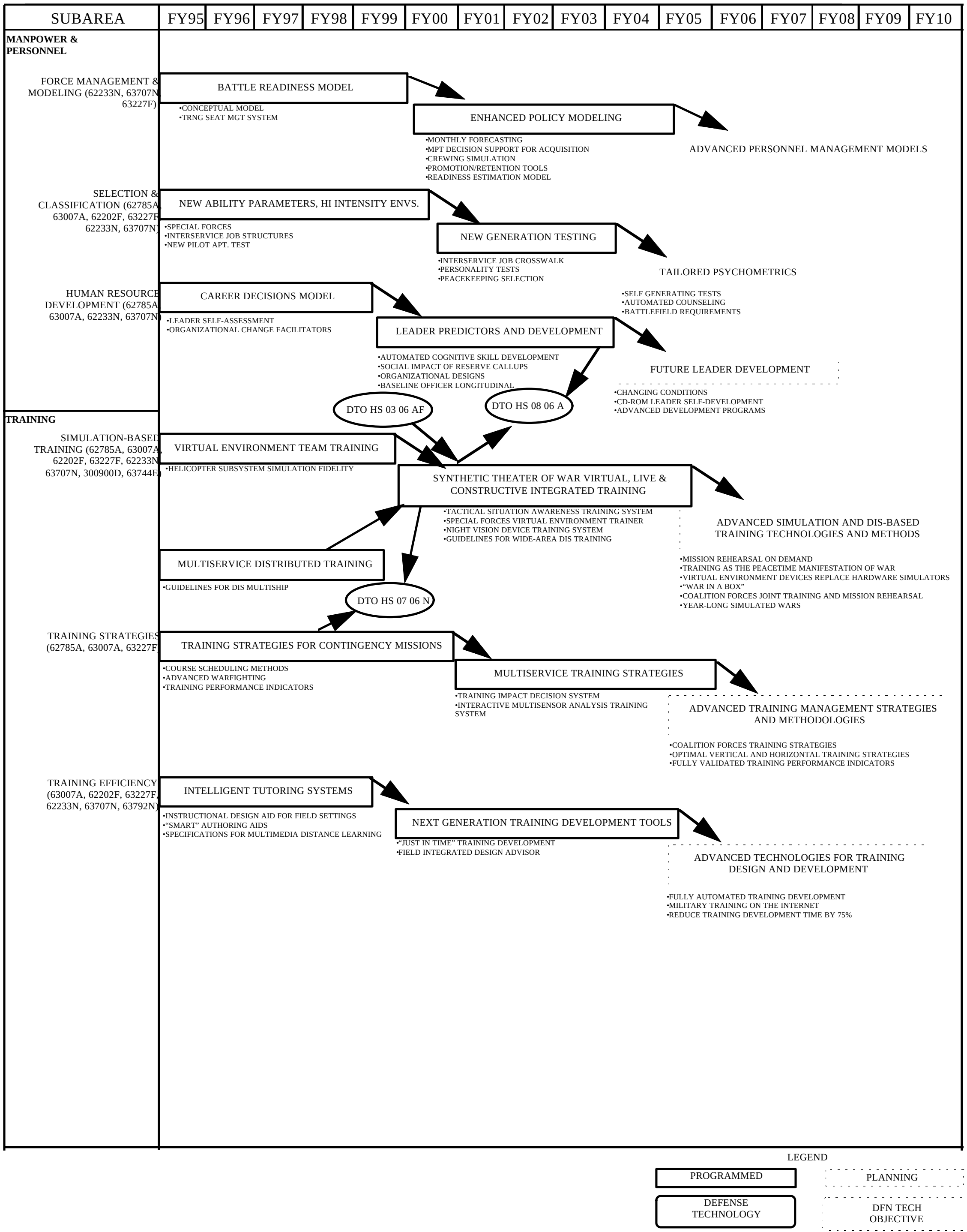


Figure IX.2. Human Systems Technology Roadmap (concluded)

4.2 Human Systems Technology Area Resources ($M)

DTOs	Program Element	$ in millions					
		FY1996	FY1997	FY1998	FY1999	FY2000	FY2001
DTO HS 01 05 A	0603001	12.5	16.2	6.3	7.0	0	0
21st Century Land							
Warrior (21CLW)	DTO Total	12.5	16.2	6.3	7.0	0	0
DTO HS 02 00 F	0602202	1.8	2.3	2.3	2.4	2.4	2.1
Advanced Aircrew Escape	0603231	6.1	6.2	6.5	7.5	8.1	8.6
	DTO Total	7.9	8.5	8.8	9.9	10.5	10.7
DTO HS 03 06 AF	0603227	4.8	4.1	3.6	0	0	0
Aircrew Distributed	0602785	0.7	1.9	2.4	0	0	0
Mission Training	0603007	0.4	0.4	0.4	0	0	0
	DTO Total	5.9	6.4	6.4	0	0	0
DTO HS 04 01 FNA	0602233	1.3	1.3	1.2	1.1	1.0	1.0
Cognitive Engineering	0602202	2.0	2.1	2.1	2.1	2.1	1.8
For Information	0603707	1.3	1.9	1.9	2.0	2.0	2.1
Dominance	0602716	0.6	0.5	0.3	0	0	0
	DTO Total	5.2	5.8	5.5	5.2	5.1	4.9
DTO HS 05 06 FN	0602122	0.6	0	0	0	0	0
Crew Station Integration	0602202	0.5	0.6	0.6	0.6	0.6	0.3
Demonstrations	0603231	2.0	1.9	1.6	2.1	2.3	2.4
	DTO Total	3.1	2.5	2.2	2.7	2.9	2.7
DTO HS 06 06 AF	0602716	0.2	0.4	0	0	0	0
Crew System Engineering	0602202	5.0	5.8	6.0	6.0	6.0	5.3
Design Tools	DTO Total	5.2	6.2	6.0	6.0	6.0	5.3
DTO HS 07 06 N	0603792	3.0	4.0	4.0	0	0	0
Advanced Embedded Trng.	DTO Total	3.0	4.0	4.0	0	0	0
DTO HS 08 06 A	0602785	1.3	1.6	1.7	1.9	1.8	0.6
Force XXI Training	0603007	--	0.3	0.4	1.4	1.7	1.7
Strategies	DTO Total	1.3	1.9	2.1	3.3	3.5	2.3
DTO HS 09 02 AF	0602202	0.6	0.4	0.4	0.4	0.4	0.3
Helmet-Mounted Sensory	0603231	6.0	5.7	4.5	2.2	0	0
Ensemble	0602705	0.8	0.8	0	0	0	0
	DTO Total	7.4	6.9	4.9	2.6	0.4	0.3

Figure IX.3. Human Systems Technology Roadmap Resources (cont.)

TOTALS MAY NOT AGREE DUE TO ROUNDING

DTO HS 10 11 F	0603106	4.1	5.0	5.8	6.2	6.8	7.7
Integrated Tech. Info. to							
Improve Maint. Perf. & Oper.	DTO Total	4.1	5.0	5.8	6.2	6.8	7.7
DTO HS 11 11 F	0603106	4.8	6.0	6.3	7.0	7.8	8.2
Logistics Tech. for Flexible							
Cont. Dep. & Ops.	DTO Total	4.8	6.0	6.3	7.0	7.8	8.2
DTO HS 12 02 F	0602202	0.7	0.8	0.8	0.8	0.8	0.7
Night Vision	0603231	0.5	1.7	2.0	3.1	5.5	5.9
Goggle Technologies	0603792	1.4	2.5	5.0	4.9	0	0
	DTO Total	2.6	5.0	7.8	8.8	6.3	6.6
DTO HS 13 02 A	0602303	0.4	0	0	0	0	0
Precision Offset, High Glide	0602786	0.5	1.2	1.2	1.3	0	0
Aerial Delivery of Vehicles,							
Munitions, and Equipment	DTO Total	0.9	1.2	1.2	1.3	0	0
DTO HS 14 05 A	0603003	27.4	25.1	17.7	6.3	0	0
Rotorcraft Pilot's Associate	DTO Total	27.4	25.1	17.7	6.3	0	0
DTO HS 15 05 A	0602786	1.7	1.1	0.9	0	0	0
Small Arms Protection for							
the Individual Combatant	DTO Total	1.7	1.1	0.9	0	0	0
DTO HS 16 05 A	0602786	0.4	0.4	0.4	0.4	0	0
Thermal Signature on							
for the Individual Combatant	DTO Total	0.4	0.4	0.4	0.4	0	0
DTO HS 17 06 A	0602786	1.5	1.5	1.5	0.9	0	0
Warfighter Systems	0602618	0.3	0.3	0	0	0	0
Modeling (WSM)	DTO Total	1.8	1.8	1.5	0.9	0	0
DTO HS 18 06 FN	0602233	0.8	1.0	1.0	1.0	1.0	1.0
Weapon System	0602201	2.1	2.0	2.2	2.3	2.3	2.2
Decision Support	0602202	1.4	1.7	1.7	1.7	1.7	1.5
	0603707	0.7	1.5	1.5	1.5	1.5	1.5
	DTO Total	5.0	6.2	6.4	6.5	6.5	6.2

Figure IX.3. Human Systems Technology Roadmap Resources (concluded)

TOTALS MAY NOT AGREE DUE TO ROUNDING

HUMAN SYSTEMS
ACRONYMS

21 CLW	21st Century Land Warrior
ACES II	Aircrew Escape System
AI 2	Advanced Image Intensifier
ARDEC	Armament Research and Development Engineering Center
ARIEM	Army Research Institute for Environmental Medicine
ARPA	Advanced Research Projects Agency
ARPA	Advanced Research Projects Agency
ATD	Advanced Technology Demonstration
ATD	Advanced Technology Demonstration
C/B	Chemical/Biological
C2	Command and Control
CATT	Combined Arms Tactical Trainer
CBPS	Chemical/Biological Protective Shelter
CCTT	Close Combat Tactical Trainer
COEA	Cost Estimate Analysis
CONUS	Continental United States
CRDA	Cooperative Research and Development Agreement
DCSPER	Deputy Chief of Staff for Personnel
DEA	Data Exchange Agreement
DI	Design Integration
Dir, E&LS (DDR&E)	Director, Environmental & Life Sciences (Director of Defense Research & Engineering)
DIS	Distributed Interactive Simulation
DLA	Defense Logistics Agency
DoD	Department of Defense
DoD	Department of Defense
DoE	Department of Energy
DWHRP	Defense Women's Health Research Program
FEMA	Federal Emergency Management Agency
M1A2 Plus	Future Main Battle Tank
FO/FAC	Forward Observer/Forward Air Controller
FYDP	Five Year Defense Plan
GPADS	Guided Parafoil Air Delivery System
GPS	Global Positioning System
HMD	Head-Mounted Display
HMMWV	High Mobility Multipurpose Wheeled Vehicle
HSI	Human System Interface
IM&D	Information Management and Display
IR	Infrared
ISS	Individual Survivability and Sustainability
ISU	Individual Sustainability
ISV	Individual Survivability
JAST	Joint Attack Strike Technology
JCS	Joint Chiefs of Staff
JIT	Just In Time
JPATS	Joint Primary Aircrew Training System
JSF	Joint Strategic Fighter
JS-LIST II	Joint Service Lightweight Integrated Suit Technology II
JSTARS SPO	Joint Surveillance Target Attack Radar System System Project Office
LS	Life Support

LW	Land Warrior
M&P	Manpower and Personnel
MANPRINT	Manpower and Personnel Integration
MANTECH	Manufacturing Technology
MCC	Microclimate Conditioning
MOA	Memorandum of Agreement
MOS	Military Occupational Specialty
MOU	Memorandum of Understanding
MPT	Manpower, Personnel, and Training
MRDAC/ OTSG	Medical Research, Development & Acquisition Command (Office of the Surgeon General)
NACES	Naval Aircrew Escape System
NASA	National Aeronautic and Space Administration
NATO	North Atlantic Treaty Organization
NFPA	National Fire Protection Association
NRDEC	Natick Research, Development & Engineering Center
NSF	National Science Foundation
OICW	Objective Individual Combat Weapon
OOTW	Operations Other Than War
PA	Performance Aiding
POS/NAV	Position/Navigation
R&DA	Research & Development Associates for Military Food & Packaging Systems, Inc.
S&T	Science and Technology
SOF	Special Operations Forces
SS	System Supportability
SSCOM	US Army Soldier Systems Command
SSV	Soldier Survivability
T	Training
TRADOC	Training & Doctrine Command
TTCP	The Technology Cooperative Program
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle
UN	United Nations
USA DAS (R&T)	United States Army Deputy Assistant Secretary for Research & Technology
USDA	United States Department of Agriculture
USMC	United States Marine Corps
USN	United States Navy
USV	Unmanned Surveillance Vehicle
VE	Virtual Environment
WPAFB	Wright Patterson Air Force Base
WSM	Warfighter Systems Modeling

X. FY 1997 DEFENSE TECHNOLOGY AREA PLAN FOR WEAPONS

1. INTRODUCTION

1.1 Definition/Scope

This technology area includes efforts devoted to armament and electronic warfare technologies for all new and upgraded non-nuclear weapons. The Weapons panel consists of three subpanels—Conventional Weapons, Directed Energy Weapons, and Electronic Warfare. The weapons technology structure is illustrated at Figure X.1. The efforts in these subpanels are directed toward providing demonstrated technology that better enables the warfighter to incapacitate or destroy enemy personnel, materiel, and infrastructure, and provide defense against and/or countermeasures to his ability to wage war.

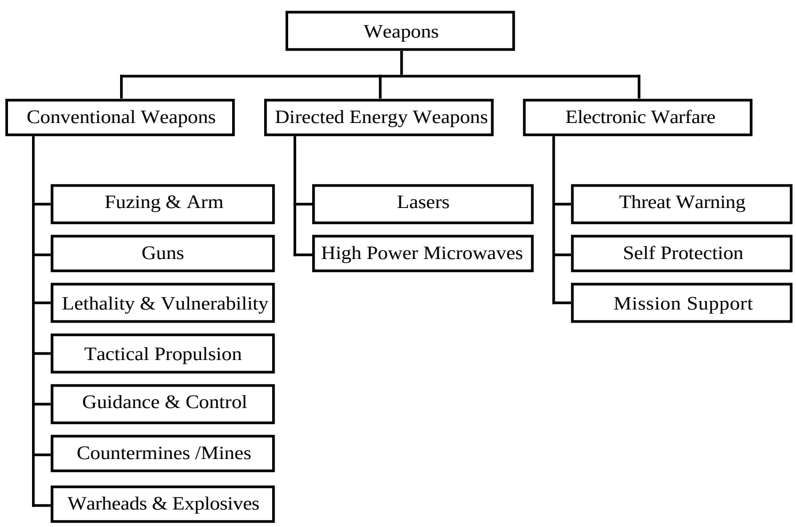


Figure X.1. Planning Structure - Weapons Technology Area

Conventional Weapons (CW) focuses on munitions, their components and launching systems, guns, tactical propulsion, bombs, rockets, guided missiles, projectiles, special warfare weapons, mortars, mines, countermine systems, torpedoes, explosive ordnance disposal, and underwater weapons and their associated combat control. The panel has seven subareas: Fuze/Safe & Arm; Guidance & Control; Guns; Lethality and Vulnerability; Mines & Countermines; Tactical Propulsion; and Warhead and Explosives.

Directed Energy Weapon (DEW) technologies are those that relate to the production and projection of a beam of intense electromagnetic energy or atomic/subatomic particles that are used as a weapon. Directed Energy weapons and devices generate energy that travels at or near the speed of light from a beam source directly to the target. Directed Energy includes the laser DEW and high power microwave DEW subareas. The only Particle Beam effort is supported by previous year funding and will not be discussed further.

Electronic Warfare (EW) is responsible for developing technology which provides U.S. military forces with the capability to maximize their unchallenged, operational use of the electromagnetic spectrum, while denying the same from the enemy by using electromagnetic means to detect and attack enemy sensor and command infrastructure systems. The underlying technologies within EW can be divided into three principal subareas: Threat Warning; Self-Protection; and Mission Support.

Editor's Note: The weapons area was previously addressed in the Conventional Weapons Technology Area Plan and the Technology Area Plan for Electronic Warfare/Directed Energy Weapons.

See Resource Appendix for funding of this Defense Technology Area.

1.2 Strategic Goals

The overarching strategic goal for weapons technology investment is to develop and transition superior weapons technology that will provide the Services with affordable and decisive military capabilities to execute future missions. The specific goals in conventional weapons mainly focus on technology for systems to destroy enemy personnel, materiel, and infrastructure, but with a growing emphasis on incapacitation through non-lethal technologies. The specific goal of the EW and DEW technology efforts is to control and exploit the electromagnetic spectrum for maximum effectiveness of U.S. military operations.

1.3 Acquisition/Warfighting Needs

Weapons technology provides the decisive military capabilities for the future. It responds to the Services' operational needs for cost-effective system upgrades and next generation systems in support of the top Joint Staff Future Warfighting Capabilities (JSFWC). The Weapons Panel technology activities directly support the Joint Warfighting Operational Needs/Capability areas of Precision Force-Strike Warfare, Joint Theater Missile Defense, Military Operations in Urban Terrain (MOUT), Joint Countermine, Electronic Warfare, Information Warfare, and Counterproliferation, and contribute support to the areas of Dominant Battlespace Knowledge, and Combat Identification.

Specific objectives of weapons technology programs address: (1) the need for affordable all-weather, day-night precision strike against projected mobile and fixed targets; (2) gun/missile systems to support the development of advanced, lighter weight air/land combat vehicles and tanks, ship and vehicle self-defense systems, and lightweight high-performance gun systems for artillery applications and naval surface fire support missions; (3) the capability to detect, identify, and jam RF weapon system sensors and advanced imaging/pseudo-imaging infrared (IR) missile seekers; (4)

projecting lethal force precisely against an enemy with minimal friendly casualties and collateral damage and development of high velocity, highly accurate conventional ballistic missile and smart fuze penetrator warhead; (5) development of technologies for advanced radar warning receivers, ESM, and ECM systems that can respond to a changing RF environment; (6) effective mine detection and neutralization capability to permit movement of forces ashore during amphibious assaults and during movement on land; (7) all-weather defense against very low observable cruise missiles, aircraft, and ballistic missiles; (8) disruption or destruction of missiles and projectiles in various phases of flight; (9) disruption or destruction of adversary communications and information systems; (10) control of space; (11) suppression of enemy air defenses; (12) undersea superiority through highly lethal underwater attack and defense capabilities against ASW/ASUW platforms at long range, in shallow water with weapons, counterweapons, and countermeasures with increased speed and reduced weight and acoustic signature; (13) real-time integration of "own-platform" sensor information with off-platform theater/battlespace information to yield situation assessment (SA), threat geolocation, and decision aides to combat identification, targeting, and damage assessment objectives; (14) the denial, degradation, and deception of enemy command, control, and navigation functions; and (15) the use of non-lethal technologies for a variety of missions. Technologies have transition potential to a wide variety of weapons systems and platforms and Figure X.2. illustrates some of the weapons technology transition opportunities. A List of Acronyms can be found at the end of this chapter.

		Years		
Subarea	**Current Baseline**	**5**	**10**	**15**
CW/Fuzing	Patriot Warhead. GBU-24. GBU-27. AGM-130. FMU-143.	Patriot Upgrade Adaptable Warhead. Protec Fuze.Smart Fuze. GBU-24.	Adv Unitary Penetra ($AMRAAM P^3I$). JDAM. JASM.	JAST 1000. GIF Dual Range Missile.
CW/G&C	SFW. AIM-9. AMRAAM. TOW. HYDRA 70.	JDAM. AMRAAM. AIM-9X. FMTI LCPK	F-117. F-22. UAV (LOCAAS). AIM-9X. GBU-24/Enhanced. Solid St Laser Seeker. LADAR. FOTT. Guided 2.75 Rocket.	JAST 1000. Dual Range Missile JASM (Powered LOCAAS). Small Smart bomb.
CW/G&C	Torpedo planar acoustic array.	Conformal Hull Array: LH7.	Broad and Sonar: MK50. ADCAP.	Biodynamic Process: LHT. ADCAP. MK50.
CW/G&C	Noise CMs: ADC. MK2.	Automatic Torpedo Attack Tracker.	Anti-Torpedo Torpedo.	LHT/ATT.
CW/G&C	MLRS Free Rocket.	Guided Extended Range Rocket.		

Figure X.2. Weapons Technology Transition Opportunities

		Years		
Subarea	Current Baseline	5	10	15
CW/Guns	M16 Rifle M16/M203 Systems	21CLW OICW	21CLW OCSW	OPW/OSW
CW/Guns	BFVS & LAV Armament. Apache Hel Armament. AC-130 Gun Ship. F-16 Armament.	AC-130 Gunship Upgrades.	BFVS, LAV & Apache Armaments Upgrades.	AAAV Upgrades. JAST Armament.
CW/Guns	Paladin 30 Km Rng. 130mm Mortar Rng.	130mm Mortar Rng & Effectiveness Improvement.	Crusader 40Km Rng.	Extended 50Km Rng.
CW/Guns	Abrams Gun/Ammo.	Abrams Ammo Upgrades.		FMBT Armament.
CW/Guns	M16A2 Rifle. M203 Grenade launcher. 12 Gauge Shotguns.	OOTW Static HPM/DE devices. Blunt Impact Munitions. EMT Pulse Vehicle Stopper.	OOTW Mobile DE devices.	OOTW DE devices for purposes other than delay/denial.
CW/Guns	Containerized Ammo Distribution Systems (CADS) exercises.	Munition Logistics nodes survivability & improvements.	Robotic teleoperated munition storage area regeneration.	Explosive mitigation alternatives.
CW/Guns	Ammo Storage vulnerable to loss with a single threat missile, ammo movement/resupply constrained to large operations and not responsive to early entry insertions.	Survivable Ammo Storage. Improved Materiel Velocity. Sea Based Resupply.		
CW/M&CM	AN/PSS-12.	IVMMD. ASTAMIDS.	HSTAMIDS. GSTAMIDS.	Mine Hunter Killer.
CW/M&CM	MICLIC.	JAMC.	ESMB. ORSMC. MCMIA.	AHMCM.
CW/M&CM		WAM	IMF.	
CW/M&CM	Hamlet's Cove /Radiant Clear.	NAVOCEANO WSC.	SABRE. CINC JIC.	

Figure X.2. Weapons Technology Transition Opportunities (cont.)

CW/M&CM	SQQ32. ASQ14. RMOP. Magic Lantern.	SQQ32 Improvement. ALMDS (improved rapid recon). RMS V4. LMRS. Rapid airborne surf zone minefield recon.	RMS P1 . RMS P2.	Multi-spectral airborne sea mine recce system. Multi-platform clandestine recon.

		Years		
Subarea	**Current Baseline**	**5**	**10**	**15**
CW/M&CM	SLQ48 (1-on-1 sea Mine Neutralization System). ML58 line charge.	RAMICS. DET/SABRE. High speed magnetic & acoustic influence sweep source components. Extended stand-off surf zone breaching.	Extended stand-off DET/SABRE Magic Carpet/ Thunder Road. Obstacle breaching Instride, distributed neutralization of VSW/Surf Zone mines.	Focused shock wave breaching system. Combined mine & obstacle clearance of the surf zone & beach zone.
CW/M&CM	Quickstrike sea mine conversion kits for MK80 series GP bombs. MK65 Quickstrike sea mine. SLMM. CAPTOR anti-submarine sea mine.	Sea Mine IFF. Remote Control (RECO). SLMM Improvement. Littoral Sea Mine.	Armed Surveillance Network.	
CW/ Warheads	BLU-109. BLU-113.	Conventional Ballistic MSL with Penetration Warhead.	Glide RV with next generation guidance systems & near real-time targetting.	Full glide RV with on-board target detect/kill.
CW/ Warheads	Bulk and Shaped Charge Warhead: MK50. MK48.	Enhanced Bubble Energy: MK50. MK48.		Explosive Driven Magnetic flux Shaped Charge.
Laser DEW	Chemical Laser and Beam Control.	Beam Control ATD. ABL Demonstrator. Preliminary SBL Ground Demos. IRCM Laser Demo.	Operational GBL ASAT. Operational ABL. SBL Demonstrator.	Operational SBL Constellation.
Laser DEW	Semiconductor Laser.		Conformal Laser Array Demo.	Fotofighter aircraft.
Laser DEW	Free Electron Laser.	1 kW Demo.		
HPM DEW	Wideband HPM.	IRCM HPM Demo. C2W/IW ATD.	Operational IRCM	Operational C2W/IW System
HPM DEW	Narrowband HPM.	Explosively powered device demo. Radar survivability demo.	Active Denial System. SEAD Demo. Space Control Demo.	Operational SEAD System.

Figure X.2. Weapons Technology Transition Opportunities (cont.)

		Years		
Subarea	**Current Baseline**	**5**	**10**	**15**
EW Threat Warning (RF)	Operational ALR-XX. SLQ-32. SEI Test Units.	ALR-XX Impr. P3; CID.	AIEWS. AIEWS;ALR-XX Impr.	JAST. Wpn Embedded.
(SA)	JMCIS.	IEWCS; SIRFC; SOF C-130.	F-15, 16, 18, 22; JSTARS,Apache/ Commanche, B-1B; Ships, AWACS.	JAST.
(EO/IR)	AAR-47.		CMWS.	
EW Self-Protection (RF)	Operational ALQ-XX. Chaff, POET. Nulka; SRBOC; SLQ-32.	ALE-50, 47. Adv. ECM Txmtr ATD. Eager ATD.	IDECM; ALQ-XX Impr. SIRFC. AIEWS. AIEWS.	JAST. SIRFC Impr. TMET Decoy.
(EO/IR)	MATES ATD. ATIRCM.	MATES ACTD. SOF DIRCM. SIIRCM.	C17, C-141, C-5, VIP A/C.	Integ AIEWS/DEW Laser Wpn. Tactical A/C SIIRCM Impr.
EW Mission Support (C2W)	Classified Platforms	IEWCS. →	→	→
(RF)	EF-111A/EA-6B.	ALQ-99 Impr.	Tactical Jamming Pod.	Tactical Jammng UAV.

Figure X.2. Weapons Technology Transition Opportunities (concluded)

2. DEFENSE TECHNOLOGY OBJECTIVES (DTO)

2.1 Conventional Weapons

WE.01.04.ANEFC	Missile Agility/Kinematic Enhancement (MAKE)
WE.02.07.AN	Land and Sea Mines
WE.05.02.F	Anti-Material Warhead Flight Test (AWFT)
WE.06.02.N	Concentric Canister Launcher (CCL) ATD
WE.07.02.A	Future Missile Technology Integration (FMTI) [Formerly TACAWS]
WE.08.02.F	Miniaturized Munition Technology (MMT) Guided Flight Test
WE.11.12.D	Advanced Unitary Penetrator (AUP)
WE.12.02.ANFH	Anti-Jam GPS Inertial Competent Munitions

WE.13.02.A	Counter Active Protection System (CAPS)
WE.14.11.A	Munitions Logistics Survivability
WE.15.02.N	Low Cost Missile
WE.16.05.A	Objective Individual Combat Weapon (OICW)
WE.17.02.F	Hammerhead.
WE.18.02.A	Direct Fire Lethality
WE.20.02AF	Non-Lethal Technologies
WE.21.02.NE	Fiber Optic Gyro Based Navigation Systems
WE.25.02.A	Multimode Airframe Technology Demonstration [Formerly LONGFOG]
WE.26.02.N	Cruise Missile Real-Time Retargeting
WE.27.02.N	Concurrently Engineered Ball-Joint Gimbal Imagery Seeker
WE.28.02.A	Low Cost Precision Kill (LCPK)
WE.29.02.N	Anti-Torpedo Torpedo ATD
WE.31.02N	Explosive Ordnance Disposal (EOD)
JWSTP.B02	Rapid Force Projection Initiative (RFPI)
JWSTP.G01	Land Mine Neutralization
JWSTP.G02	Land Mine Detection
JWSTP.G03	Land Countermine
JWSTP.G04	Littoral Mine Obstacle Detection
JWSTP.G05	Littoral Mine Obstacle Clearance
JWSTP.G06	Littoral Countermine
JWSTP.G07	Sea Mine Detection
JWSTP.G08	Sea Mine Clearance
JWSTP.G09	Sea Countermine
JWSTP.G10	Joint Countermine ACTD

2.2 Directed Energy

WE.04.04.CF	High Power Lasers for Theater Missile Defense
WE.10.08.F	Ground-Based Laser ASAT
WE.19.08.F	HPM/Laser Aircraft Self Protect Missile Countermeasures
WE.22.09.F	High Power Microwave C2W/IW Technology

2.3 Electronic Warfare

WE.03.08.ANF	Combat Aircraft (A/C) Infrared Countermeasures (IRCM)
WE.09.08.E	Defense Advanced Research Projects Agency (DARPA)/Tri-Service IR Countermeasures (IRCM) Laser Technology
WE.23.08.ANF	Modern Network Command and Control Warfare (C2W) Technology
WE.24.08.ANF	Sensor Fusion/Integrated Situation Assessment Technology
WE.30.08.N	Advanced Electronic Countermeasures (ECM) Transmitter for Ship Self Defense
H02	Ship Defense Against IR Missiles (proposed ACTD)
H03	Multispectral Countermeasures ATD
H06	Miniature Air-Launched Decoy ACTD

3. TECHNOLOGY

3.1 CW—Fuzing/Safe & Arm

3.1.1 Warfighting Needs

The DoD requires Guidance Integrated Fuzing (GIF) that will provide increased warhead lethality by 20-30% over existing systems and G&C/fuzing that will cost 20% less than current systems, enabling more single shot kills, fewer sorties and/or quicker capture of air superiority, surface, and undersea target neutralization, supporting the JSFWC. Transition opportunities include AMRAAM, Sidewinder, Patriot, and anti-surface missiles such as ARMs, JDAM, JSOW, and the torpedo defense programs SDWS and SSTD. Significant increases in penetration depths translate into at least 50% more hard targets that can be destroyed or disabled with single shots. Smaller, more lethal weapons, will enhance the JAST and the F-22. Hard Target Smart Fuze accuracy is a critical area so buried hard targets can also be defeated. Smart fuzes will guide the global penetrator warheads loaded with explosives that withstand 400% higher acceleration than existing systems. A Micro Electro Mechanical Systems approach will allow a common Safe & Arm device for all undersea weapons. Possible transitions include the Lightweight Hybrid Torpedo and Anti-Torpedo Torpedo.

3.1.2 Overview

3.1.2.1 Goals and Timeframes

Application/Mission	Short-term (1-2 Years)	Mid-term (3-5 Years)	Long-term (6+ Years)
Hard Target Penetration Technology	Development of shock and temperature insensitive components. Non-volatile memory for hard target test events records.	Advance Hd Tgt L/V analysis, including synergistic effects of blast & fragmentation warheads & maturation of statistical techniques to qualify uncertainties. The results should reduce the need for testing and produce cost savings & time of 30:1 (Test Analysis). Penetrate reinforced concrete targets up to 30 feet thick.	Hd Tgt penetrating radar actively determines stratification of penetration media to determine invoid burst point. Use adv kill mechanisms to defeat electronic components and Chem/Biol agents. Use multi-sensor, non-inertial void sensors for hd tgt penetration fuzing.
Counter Air Fuze Technology.	Architecture for modular missile & environment simul based on JMASS. Imaging IR analysis and design. Massively parallel processing for aimpoint enhancement. Clutter discrimination algorithm.	Proximity and GIF modules for simulation library. Imaging IR Fuze/Safe&Arm & Focus warhead integration. Distributed initiation systems. Low energy S&A devices.	Imaging IR fuze for dual-mode/dual-role missile application. Demonstrate GIF aimable warhead capabilities. Increase operational range for IR fuzes. Increased CM capabilities for active IR fuzes. Low cost electronic S&A devices.
Anti-Surface Fuze Technology.	Conduct JDAM target ECM requirements analysis and susceptibility testing. Demo adv GPS based artillery registration.	Demo JDAM ECM resistant proximity fuze based on MMIC architecture. Demo stand-off fuze against reactive/active armor. Demo miniaturized electronic fuzing for OICW bursting munition.	Implement waveform agile ECM hardened sensor for PGM and GP bomb anti-jam capability. Demo detection of CM targets in clutter for sensor-fuzed weapons. Eliminate UXO.
Common Undersea Weapon Fuze/Safe & Arming.	Demo reduced power requirement for EM fuze housed in composite material.	Hybrid Micro Electro Mechanical Systems (MEMS) F/S&A for 6.25" diameter undersea weapon.	Integrate MEMS into a common F/S&A for all weapons.

3.1.2.2 Major Technical Challenges. Fuzing/Safe & Arm challenges include all-weather, clutter ECM and chaff performance, high resolution target imaging, safe and affordable multi-mode warhead initiation and high-fidelity simulations for modeling system performance. For improved weapon lethality, challenges include cockpit selectable robust algorithms for determining target parameters and computing warhead events in real-time, high-fidelity sensors and affordable high-shock survival components.

Challenges also include development of a common, small, reliable safe and arm device for undersea weapons while retaining the multiple environmental interlocks required to satisfy current safety standards.

3.1.2.3 Related Federal and Private Sector Efforts. The highly specialized nature of Fuzing/Safe & Arm technology does not readily lend itself to commercial IR&D efforts. In this area most benefits are derived indirectly from advances in related areas of electronic research.

3.1.3 Investment

3.1.3.1 Technology Demonstrations. Technology demonstrations include those supporting the Defense Technology Objectives:

- Demonstrate a conformable antenna array technology for use as a fuze sensor in adjunct guidance anti-radiation homing mode.
- Demonstrate torpedo guidance integrated fuze against multiple targets in countermeasures.
- Demonstrate an optical Safe/Arm/Fire device to show that RF radiation will not trigger explosive elements.

3.1.3.2 Technology Development. Technology development efforts support demonstrations described above, to lay the foundation for demonstration and address longer-term military applications. Major task areas are:

- Guidance Integrated Fuzing (GIF) to develop technology that will enhance overall weapon system effectiveness.
- Advanced Initiation Systems to utilize less sensitive explosive components and require a unique firing pulse for initiation.
- Hard Target Penetration Fuze to provide increased effectiveness of weapons that will penetrate greater than 27 ft of reinforced concrete (300% increase) and significantly increase the fuze’s ability to recognize target parameters and make real-time decisions.
- Gun Munitions Fuzing to develop and demonstrate fuze technology to optimize warhead performance under evolving electronic countermeasures.

3.1.3.3 Basic Research. Basic research studies provide an essential foundation for the weapons technology required to defeat future threats and ensure that our forces can maintain a technological edge. Research is performed by a blend of university and in-house components uniquely suited to supplying the technologies needed for advanced weapons systems. Research related to mathematics and computer science, physics, chemistry, materials science, electronics, and mechanics all support our weapons technology requirements.

3.2 CW—Guidance & Control

3.2.1 Warfighting Needs

Future warfighting will require more affordable precision guided weapons which are smaller, lighter, and significantly more effective than current systems. This requires Guidance and Control (G&C) that supports a three to one reduction in the number of Precision Guided Munitions (PGMs) required to defeat high-priority targets including time-critical mobile targets (SCUD launchers). As an example, the guided Multiple Launch Rocket System (MLRS) will reduce the number of rockets needed to defeat targets by factors of 8 to > 100, over existing systems depending upon target type and range, and result in a cost/kill reduced by a factor of 5. A decrease in false target acquisition and track over currently fielded systems will reduce weapons launched per target destroyed by four-to-one while reducing the number of sorties required to destroy a given target thereby reducing aircraft losses. G&C also supports high accuracy that will severely reduce collateral damage and allow use of smaller warheads. Future seekers will provide all-weather, completely autonomous operation, with increased standoff ranges against a broad target set in a very hostile low observable environment and a 40% increase in BMD interceptor effectiveness and reduced incidents of fratricide. G&C will also support the rapid response upgrade in weapon system lethality and addition of global range for conventional ballistic missiles. Potential transitions: MLRS, TOW, JDAM, AMRAAM, AIM-9X, LHT/ATT, MTRACS, STINGER and ADCAP Block Upgrades.

3.2.2 Overview

3.2.2.1 Goals and Timeframes. The investment strategy being followed is to improve the effectiveness of weapons G&C systems so that fewer weapons are needed per target. This reduces the overall cost of expending such weapons in combat, and supports a parsimonious acquisition philosophy. We focus on affordability by emphasizing simulation to reduce research and development costs and to improve training and readiness; by linking G&C component development with manufacturing S&T; by utilizing commercial products when feasible; by increasing emphasis on hardware and software co-design, and by identifying critical shelf-life issues early in the acquisition cycle. The goals are:

Application/Mission	Short-term (1-2 Years)	Mid-term (3-5 Years)	Long-term (6+ Years)
Undersea Weapon Target Detection and Homing	Prototype Intelligent Controller directing the weapon mission in harsh shallow water environments. Conformal hull and broad and acoustic arrays.	Fusion of multisensor & multiprocessor data. Simultion Based Design of the Light-Weight Hybrid Torpedo.	Post-launch relocation of CMs and targets by broad and biodynamic processing. Environmentally adaptive detection, classification, homing warhead placement.
Undersea Weapons Platform Defense.	Tactical decision and uncertainty management algorithms. Baseline Anti-Torpedo Torpedo capabili-ty for surface ships and submarines.	Multisensor torpedo classifier and CM employment algorithms. Smart Adaptive CM and ATT demo in CM environment.	Rules for new SSN and next generation surface ship combat control. Full capability torpedo defense for surface ships including defense against salvo attack.
Fire Support.	Demo advanced imaging autotracker algorithms which meet the requirements of FMTI. Demo Long Range Fiber Optic Msl capable of ranges greater than 40km. Complete guided flight test of semi-rigid wing platform.	Demo low-cost ruggedized, miniature inertial components for use in msl guidance, position loc, nav, and fire control. Dev next gen of laser diode HWIL scene projectors. RFPI ACTD culminating with large scale field exercises. Demo long range fiber optic dispenser with improved pack stability over military environment	
Air Defense.	Demo sensor suite for air defense Msl target acquisition. Complete LADAR scatter field test. Demo low-cost ruggedized pigtailing ap-proach for lithium niobate integrated optic wave guides. Demo multirole survivability radar in midcourse msl flight test.	Complete DIAL remote spectroscopy of targets. Demo capability to perform NCTR of air targets with special algorithms using Air Defense Radar. Demo Adv datalink tech capability including data compression, spread spectrum & CM techniques for secure msl command & control. Dev integrated circuitry for use in HWIL simulation of RF guided missiles. Demo FMTI technology in flight test. Upgrade to STINGER through integration with IIR Seeker.	FMTI Phase II ATD complete with 8-10 missile flights and soldier testing in realistic scenarios.

Application/Mission	Short-term (1-2 Years)	Mid-term (3-5 Years)	Long-term (6+ Years)
Close Combat	Demo north alignment to within 5-10 mrad in under 3 min at a production cost of <$5K. Complete simulations & obtain accuracy assess for alternative strapdown guidance concepts. Demo a G&C technique for precision air delivery systems. Demo a minimum volume electronic controller for electro-mechanical actuators.	Dev the hardware & software for an imaging seeker that can auto acquire and select the impact point on a target. Demo adv terminal homing auto-tracker in minimum sized, low power package. Demo an unmanned autonomous gnd veh nav, & tgt det capability.	Low-cost precision kill 2.75 inch guided rocket flight and user test.
Dev inexpensive electronically scanned array hardware for missile seekers.	Demo tracking ability with small number (10-15) of xmt/receive units made with conventional hardware & mounted on conical surface of radome for 13 in missile.		
Dev signal processor to rapidly identify selected target in air defense site and select aimpoint.		A signal processor with neural net algorithms to guide to a selected tgt from any attack aspect in JSOW size weapon.	
Dev gimballess 94 GHz seeker tracker concept for SEAD applications.		94 GHz gimballess seeker that tracks at least 30° off boresite.	Frequency-adaptive antenna system with no moving parts.
Dev high frame-to-frame image compression for application to bomb damage indication via imager datalinked to damage assessor.	Demo 300:1 image compression dynamically at 30 Hz or higher frame rate.	Demo 1000:1 image compression at 100 Hz frame rate.	
Defeat Fixed High Value Targets.	Dev anti-jam GPS guidance system. Low-cost ($3-5K) increment for substantial anti-jam performance.	Demo AJ GPS/INS guidance on JDAM type flight vehicle in heavy jamming environment. Maintain current GPS/INS accuracies.	Dev and demo intelligent GPS/INS guidance system. Increase performance against multiple (more than 3) high power jammers.
Defeat Fixed High Value Targets.	Demo small, low-cost FOG IMU for tactical applications. Cost goal is $6K for 25 cubic in IMU with <1 deg/hr drift rate.	Dev & demo very low cost (<$2K) micro-machined IMUs with tactical (1-10 deg/hr) drift rate.	Dev multiple sensor using MEMS tech to provide tactical grade performance for <$1K/IMU.

Application/Mission	Short-term (1-2 Years)	Mid-term (3-5 Years)	Long-term (6+ Years)
Demo all-weather seeker.	Demo basic SAR seeker design which will integrate with a GBU-15.	Free flt test 3 GBU-15s con-figured with SAR seekers to demo integrated munition performance.	Demo adv short response mission planning, real-time targeting, and reduced seeker cost.
Dev and demo precision LADAR seekers.	Dev LADAR seeker designs utilizing currently available technology.	Build & captive flt test adv tech LADAR seeker designs for the Small Smart Bomb & for the Warrior.	Utilizing further LADAR tech developments, build & evaluate advanced tech LADAR seeker for the Dual Range Missile.

3.2.2.2 Major Technical Challenges. Guidance and Control challenges include design and manufacture of low-cost, high-performance G&C components; multi-mode/multi-spectral seekers; high-speed signal and image processing; reliable aimpoint selection; jam-resistant data links; miniaturization and hardening of inertial measurement units. A major undersea weapon G&C challenge is to provide undersea weapon performance in the adverse, harsh, shallow-water environment equivalent to deep water capability. Quiet, slow-or-bottomed targets must be tracked, but engagements in the cluttered, congested littoral zone demand fast decisions and reaction because of the close-in encounters. Additional challenges:

- Multispectral missile seekers to improve lethality in the presence of countermeasures.
- Precision guidance of small-diameter weapons to support the Army's peace-keeping role.
- Enhanced air defense target acquisition including masked targets to increase survivability.
- Automatic target recognition to reduce collateral damage and fratricide.

3.2.2.3 Related Federal and Private Sector Efforts. Advances in computer technology have greatly aided G&C. Automotive interests in inertial sensors help tremendously in cost reduction. There are many SBIR tasks that support Guidance and Control efforts. Much of the service and industry developed guidance and control technology is distributed through the Guidance & Control Information Analysis Center (GACIAC). Significant industry IR&D is performed in this area.

3.2.3 Investment

The investment strategy is to improve effectiveness of G&C systems so that fewer weapons are needed per target.

3.2.3.1 Technology Demonstrations. Technology demonstrations which include those supporting the Defense Technology Objectives:

- Missile Agility/Kinematic Enhancement (MAKE) (WE.01).

- Low Cost Missile (WE.15).
- Concentric Canister Launcher (WE.06).
- Anti-Jam GPS/Inertial Competent Munitions (WE.12).
- Miniaturized Munition Technology Guided Flight Test (WE.08).
- Fiber Optic Gyro Based Navigation Systems (WE.21).
- Hammerhead (WE.17).
- Future Missile Technology Integration (FMTI) [Formerly TACAWS] (WE.07).
- Concurrently Engineered Ball Joint Seeker (WE.27).
- Anti-Torpedo Torpedo (WE.29).

Additionally, the following demonstrations are planned:

EFOG-M ATD. Demonstrate a fiberoptic guided missile system capable of multipurpose precision kill to 15 km range, high survivability through standby and defilade launch and day night/adverse weather operation. Deliveries of systems will begin in 1998 in support of the RFPI ACTD.

Guided MLRS ATD. Demonstrate significant (x20) accuracy improvement of the MLRS extended range free rocket by addition of a low cost guidance and control system. Flight tests will be conducted in 1997-98 in support of the RFPI ACTD.

Precision Guided Mortar Munition (PGMM) ATD. Demonstrate a precision (2 mils) guided mortar concept using advanced G&C technology and integrated manportable fire control to ranges in excess of 15 km in 1997, as part of RFPI ACTD.

2.75” Anti Air TD. Demonstrate a form fit imaging infrared seeker, which could be integrated into a 2.75” anti air missile (Stinger) to give it significantly increased (x2-3) engagement capability against air targets in clutter.

RFPI ACTD. Rapid Force Projection Initiative will demonstrate automated target transfer from forward sensors to air transportable standoff killers with the capability to engage armor and other high value targets beyond traditional direct fire ranges. A major system field exercise using Army light forces will occur in FY 98

Strike Weapons Adaptable Video and Data. This is a next generation, podless video and data link system for weapons control. The improved weapon control performance, real-time BDA and real-time targeting capability accruing from this technology development will reduce cost per kill through greater first pass success, lower strike aircraft vulnerability, and utilization of fewer assets.

Shallow Water G&C. This effort provides increased torpedo capability through new detection, classification, and environmental adaptation processing algorithms operating within the structure of a fuzzy-logic based torpedo intelligent controller. Achievement of the goals would provide a 30% to 50% (site dependent) improvement in performance for current weapons in shallow water environments. Transition targets are the MK50 and the MK48 ADCAP torpedoes.

3.2.3.2 Technology Development. Technology development efforts support demonstrations described above, to lay the foundation for demonstration and address longer-term military applications. Major task areas are:

- Image and Signal Processing, which includes collecting and analyzing large amounts of data, correlation techniques, and algorithms for acquiring and classifying and identifying targets.
- Software and Simulation which includes imbedded software development and simulation of guided systems and synthetic scene generation.
- Radiation Guidance which includes acoustic, RF, MMW, Laser Radar (LADAR), IR seekers, multi-mode seekers, and data links.
- Guidance, Navigation, and Control Components which includes inertial sensors and seeker components, radomes, actuators, and unique structural elements.

3.2.3.3 Basic Research. Some relevant technologies are: Active control, Fuzzy Logic, Neural Nets, Intelligent Control, Lower order spectral analysis, T-Matrix Target Modeling, Data fusion procedures, Tracking techniques, High heat flux density, Wake characterization, classification sorting methods, situational awareness, and transducer material - Piezo composites.

3.3 CW—Guns

3.3.1 Warfighting Needs

The DoD requires capabilities of improved range penetration and weapon system effectiveness at lower total acquisition cost over existing systems. The Objective Individual Combat Weapon will deliver 3-4 times the hit probability of existing weapons beyond 500 m and an all-new defilade target attack capability out to 300 m. Transition of the Extended Range Artillery Projectile XM982 will immediately enhance the range of existing 155mm weapons and extend the range of developmental 155mm weapon systems up to 50km. A 120mm ETC tank gun will potentially provide 50% increase in kinetic energy and 10% increase in armor penetration over current systems. Non-conventional weapons technologies will provide the field commander with a capability to tailor target effects from less-than-lethal to lethal for small caliber weapons against lightly armored materiel and personnel. Ten percent (10%) more powerful, yet less sensitive, energetic materials will enhance explosively-formed penetrator kill capability. Selective-mode warheads will be demonstrated which can defeat both a heavy armored target (10-20% increase in performance compared to Javelin) and a lightly armored target (4-fold increase in lethality as compared to a standard shaped charge). Potential transitions include: STAFF and upgrades for AAAV, BFVS, CIWS, Abrams, Paladin, Crusader, and Patriot.

3.3.2 Overview

3.3.2.1 Goals and Timeframes. The goals are to develop technologies for small, medium, and large caliber guns, gun propellants, power supplies/conditioning, and fire control, with enhanced performance and compact, lightweight configurations at affordable costs. A Joint Army/DNA electro-thermal-chemical (ETC) gun program has been developed which will mature technologies needed for the 120mm ETC tank gun. The major goals are:

Application/Mission	Short-term (1-2 Years)	Mid-term (3-5 Years)	Long-term (6+ Years)
Improve effectiveness & survivability of vulnerable munitions logistics nodes, especially for joint task force insertion into undeveloped airhead & seaports.	Demo prototype equipment for materiel velocity improvements at ports and airheads with 40-80% faster airhead clearance, 20-30% faster drop zone clearance.	Tech Demo software & prototype allowing 50-60% reduced ammo storage size with 100% survivability improvement and 25-31% fewer forklifts, participate TURBOCADS, FREEDOM BANNER	
21CLW Objective Individual and Crew Serviced Weapons.	Demo OICW system proto-type, 12lbs, PH = .5 @500m, .3@ 1000m, Probability of Incapacitation .2 against defilade target at 300 m	Demo OCSW prototype weighing less than 38lbs.	Demo OICW and OCSW in 21CLW Battle Lab experiments.
Tank lethality enhance-ments.	Demo 40-50% increased penetration capability for KE defeat of explosive reactive armor (ERA)	Demo an integrated 120 mm KE Ctg defeat of 2005 ERA and 30% increase in system accuracy under stationary conditions over M829A2/ M1A2	
Non-lethal weapons for operations other-than-war, e.g., crowd control.	Demo non-penetrating anti-personnel blunt impact munitions, launched from platforms (M16A2, 40mm M203GL, 12 Gauge shot-guns, etc) for both point target and crowds at 10-100 m. Demo DE Device over delay/denial.	Demo an electro-magnetic pulse vehicle stopper. Complete acoustic device health and safety assessment.	Demo advanced non-lethal concepts. Demo mobile DE device.
Direct fire lethality, range, system performance enhance-ment alternatives for future combat vehicles.	Demo medium caliber (EM) gun technologies for amphibious land vehicles with 0.3 MJ muzzle energy, 3 salvo/5rds per salvo, 300 rds/min and penetration effectiveness at 1000m.		

Application/Mission	Short-term (1-2 Years)	Mid-term (3-5 Years)	Long-term (6+ Years)
Improve indirect fire capabilities for artillery and mortars.	Demo extended range artillery projectile (ERA /XM982) capable of immediately enhancing the range of existing 155mm weapons and extending the range of the developmental 155mm howitzer system to 50km.	Demo 155mm Lt Wt Automatic Howitzer with 25% more rapid emplacement and 50% higher rate of fire. Demo precision guided mortar munition with first rd point/armor target effectiveness at 15km.	
System performance enhancement for future main battle tank.	Demo 40% kinetic energy increase in 120mm.	Demo 17MJ Kinetic energy at muzzle in 120 mm XM291 (10kg projectile launched at 1825 m/s)	Transition ETC technology for PIPs and/or future main battle tank applications.
System performance enhancement for Naval surface combatants.	Demo medium caliber resin/ carbon fiber composite barrels with 50% increased mean time between failure for future naval gun system.	Demo ETC technologies capable of 22MJ muzzle energies with a 5 inch gun system.	Transition ETC technologies for PIP and/or Naval surface combatants.

3.3.2.2 Major Technical Challenges. Gun challenges include packaging constraints for ETC technologies that provide compact, high efficient plasma ignitors at 22MJ muzzle energy, new high-energy-density/propellant formulation, consistent repeat rate and desirable life-cycle of pulse forming network; advanced medium caliber composite barrel with high-efficiency rail design, compact, and affordable pulse and prime power system and ammunition handling technologies for high rate of fire; other challenges include OICW with cost effective, light weight and efficiently integrated weapon/automated fire control systems. Technologies for ERA/XM982 with multi-functional electronic fuzing module, base burner, forward rocket motor, and cargo expulsion and technologies for 140mm tank lethality without the burden of 140mm ammunition for the FMBT.

3.3.2.3 Related Federal and Private Sector Efforts. Commercial advances in metallurgy support guns technology efforts These efforts are closely integrated with all DoD in-house efforts through JDL Reliance.

3.3.3 Investment

3.3.3.1 Technology Demonstrations. Gun Technology demonstrations include:

- Munitions Logistics Survivability (WE.14).
- Direct Fire Lethality (WE.18)
- Non-Lethal Technology (WE.20).
- Objective Individual Combat Weapon (OICW) (WE.16).

- Precision Guided Motor Munitions (ATD) and Low Cost Competent Munitions.
- Lightweight Automated 155mm Howitzer. Demonstrate technologies as part of the killers in the RFPI ACTD (BO2).

Additional technology demonstrations include:

- Cannon Caliber EM Gun to demonstrate a prototype medium caliber EM launcher system to defeat light armor or hard targets at 1000 meter ranges.
- Army/DNA Joint Program to demonstrate 140mm lethality from a 120mm ETC system (XM291 cannon and pulsed power) in a configuration compatible with the M1A2.
- Navy/DNA Joint Program for Future Naval Surface Combatants to demonstrate ETC technologies capable of 22Mj energies with a 5 inch gun system.

3.3.3.2 Technology Development. Technology development efforts support demonstrations described above, to lay the foundation for demonstration and address longer-term military applications. Major task areas are:

- Small Caliber systems to develop technologies for future individual and crew served small arms weapon/munitions systems yielding enhanced effectiveness and sustainability.
- Medium Caliber systems to develop higher fidelity gun systems models for integration into the Army's "Battle Lab Simulation Environment" to provide a new capability for gun system tradeoffs.
- Large Caliber systems to develop guided mortar munitions, extended range artillery, high capacity artillery projectiles, ETC tank gun, low cost munitions, and increased smart submunitions.
- Future generic gun technologies to provide variable level target effects.

3.3.3.3 Basic Research. Research in mathematics, chemistry, physics, computer science, materials science, electronics, and mechanics all support critical technology requirements for future armament systems. Focused research in the penetration physics of hypervelocity projectiles and research in high energy density power supplies support future electric gun requirements. These basic research studies provide an essential foundation for the gun system technology required to defeat future threats and ensure that our forces can maintain a technological edge.

3.4 CW—Lethality & Vulnerability (L&V)

3.4.1 Warfighting Needs

The DoD requires the ability to accurately assess the lethality of US weapons and the vulnerability of US systems. Without this capability, it is impossible to assess the US posture in future conflicts or the advantages to be gained by pending US weapon/platform developments or threats posed by foreign developments. L&V investments yield a 5:1 payoff early in the design phase of the development cycle, providing the means for optimizing conventional weapon technologies. The timely use of L&V analyses support the warfighter through reduced US casualties and enhanced battlefield performance. Formerly, lethality assessments were largely based upon experimentation on actual equipment, a prohibitively costly procedure. Through L&V, analytical tools are being developed which reduce experimentation with a documented investment payback of 30:1. Common software architectures have led to standardized methodologies across the four Services, leading to traceable, high confidence predictions of friendly weapon lethality and significantly increased survivability of friendly personnel and systems. Transition of these tools yield validated payoffs in developmental and inventory systems, support for Cost Operational Effectiveness Analyses (COEAs) and fulfillment of Live Fire Testing requirements.

3.4.2 Overview

3.4.2.1 Goals and Timeframes. The major goals for L&V are to support the weapons community through the provision of Modeling and Simulation (M&S) tools and databases. Programs are phased so as to concentrate on the production of methodologies, capabilities, and environments of general utility in the near term (1-2 years) in order to support high payoffs in the mid-term (3+years). The goals are development of tools in the following areas:

Application/Mission	Short-term (1-2 Years)	Mid-term (3-5 Years)	Long-term (6+ Years)
Primary Penetrator Phenomenology.	Hit-to-Kill (TBM). Special Armor Penetrator. Concrete Penetration	Exo-atmos. Intercept. Hypervelocity Meth.	Validation of deep, hardened target method.
Fragment/Debris Phenomenology.	Characterize Current Materials. Component Dys. Analyses.	Reactive Materials. Hypervelocity Impact.	Physics based debris generation.
Blast and Shock Phenomenology.	Structural Defeat. Shock Propagation.	Advanced Materials Response. Complex Env. Gen.	Accurate Prediction for hardened buried targets.
Fire and Fumes Phenomenology.	Personnel Effects. Fire Initiation Models.	Fire Propagation. Toxic Fume Dispersion.	Accurate solution for deep, hardened targets.

Application/Mission	Short-term (1-2 Years)	Mid-term (3-5 Years)	Long-term (6+ Years)
Damaged Target Response Models.	6-DOF Models for A/C. Improved Technology for assessment of degraded performance.	Extension of Method to Foreign system.	Accurate Models of Battle Damage Assessment.
L&V Supporting Technologies.	Adv Tgt Geometry Technology. Cone and solid core Geometry Analysis. Tgt Uncertainty Mod.	Statistical Technology. Standard Software Env. for L&V analyses.	Real-time connectivity with DIS.

3.4.2.2 Major Technical Challenges. Developing statistically reliable predictions of target damage resulting from all sources and combinations of ballistic mechanisms (penetrator, fragments, blast, shock, fire, etc); "Performance/Utility Prediction": Relating target damage states to diminished system performance; "L&V Software Environments": Developing reliable and extensive computer environments to support expeditious code reconfiguration.

3.4.2.3 Related Federal and Private Sector Efforts. Many of the L/V products and codes are distributed to other government organizations and industry through the Survivability Vulnerability Information Analysis Center (SURVIAC). It is estimated that industry uses L/V products in support of government analyses at a funding level of approximately $40M per year. It is expected this figure will increase with the continued "right sizing" of the Federal defense workforce. With the cutting of defense spending for procurement of major weapons platforms, the need for analyses using constructive models or man-in-the-loop distributed interactive simulations will require more information to be made available to evaluate technology upgrades and to justify new procurement programs. The basis for these decisions is in part L&V modeling.

In the area of L&V, many civilian agencies both use and contribute to DoD results. In addition to routine applications to law enforcement agencies, shock-trauma units in hospitals are part of the same injury evaluation effort. Much of the damage assessment technique has been developed by the American Association of Automobile Medicine and related medical organizations.

3.4.3 Investment

3.4.3.1. Technology Demonstrations. Lethality & Vulnerability demonstrations include:

- Demonstrate and validate analytical extension to the penetration model to predict scaling.

3.4.3.2 Technology Development. Technology development efforts support demonstrations described above, to lay the foundation for demonstration and address longer-term military applications. Major task areas are:

- Primary Penetrator Phenomenology to develop algorithms that predict defeat of armor and protective cover.
- Fragment/Debris Phenomenology to develop rapidly accurate algorithms that predict fragment penetration.
- Ballistic Blast and Shock Phenomenology to predict complex blast wave environments, target structural response, and component failure in combination with other L&V tools.
- Fire and Fumes Phenomenology to account for catastrophic effects of fires and hazardous fumes.
- Advanced simulations to model important synergistic effects of multiple environments.
- Damaged target response to provide a sound link relating combat damage to target residual capability and post-attack damage assessment.
- Supporting technologies to exploit computer science, graphic techniques, and advanced statistical techniques to enhance the fidelity of and confidence in L&V analyses.

3.4.3.3 Basic Research. Scientific computing research feeds the performance modeling of weapon systems and components, as well as our weapons design process. Broad-based research programs in ballistic sciences support provide essential algorithms and data required to support L&V analyses of advanced warfighting concepts.

3.5 CW—Mines & Countermeasures

The Mines and Countermine subpanel area includes technology efforts in the areas of land and sea mines, Humanitarian Demining, Explosive Ordnance Disposal (EOD) and Joint Countermine.

3.5.1 Warfighting Needs

Emerging mine and countermine technologies will provide commanders the ability to dominate the battlespace. Mine technology addresses the need for the location and tracking of a broad spectrum of combatants on land and in coastal environments, minefield communications, such as Identify Friend or Foe (IFF), and sensor fusion for enhanced minefield effectiveness. Countermine systems give the operational forces the flexibility to control the sea and to enhance survivability and conduct amphibious and ground combat operations. New countermine technologies will provide high confidence in the surveillance, reconnaissance, detection, avoidance, force protection, in-stride breaching/clearing of potential sea and/or land minefields and obstacles.

3.5.2 Overview

3.5.2.1 Goals and Timeframes.

Application/Mission	Short-term (1-2 Years)	Mid-term (3-5 Years)	Long-term (6+ Years)
Humanitarian Demining	Build on Congressional Special Interest Program to demonstrate COTS equipment for mine detection and clearance.	Develop training initiatives that address multiple languages, detection of mines from aerial and ground platforms, low-cost neutralization, protective systems for personnel and clearance verification technologies.	Long term thrusts will be derived from the Countermine Program, the UXO Clearance Program, the EOD/LIC Program and Special Operations Technology Developments but specific for the demining mission.
EOD	Develop Diver hand held sonar that images threat out to 40 meters.	Autonomous subsumptive robotics for clearance of small surface UXO.	HMMV mounted laser neutralization system to increase standoff to 250 meters.
Force Protection	Improve current means for protection of soft-skinned vehicles from blast and fragment effects of AT and AP mines. Improve individual protection materials. Develop a C4I architecture to allow for digital characterization of mined areas.	Develop acoustic, seismic and thermal technologies to enhance mine detection and clearance missions. Demonstrate a real-time automated surveillance and reconnaissance system capability to characterize a mine infested area. Demonstrate blast deflection/energy absorption enhancements for individual soldiers and ground platforms.	Integrate all countermine efforts on a military sufficient platform for demonstration of Command and Control. Continue vehicle design analysis to enhance mine blast protection for military and commercial soft-skinned vehicles.

Application/Mission	Short-term (1-2 Years)	Mid-term (3-5 Years)	Long-term (6+ Years)
Land Mine Detection	Continue application development of multiple technologies and data fusion combined with ATR to enhance detection requirements. Explore passive IR with active laser, downlooking ground penetrating radar and synthetic aperture radar technologies to further ground-based countermine system capabilities to detect and destroy mines.	Demonstrate forward looking radar and evaluate potential enhancements for providing greater standoff and enhanced weather capability. Evaluate hyperspectral and multispectral technologies to provide performance enhancements to both the airborne and ground based detection systems. Investigate acoustic and seismic technologies for ground based detection of mines. Investigate passive IR/microwave detection technologies to identify scattermines.	Demonstrate hyperspectral/multi-spectral technologies. Demonstrate acoustic and seismic performance enhancement of ground based detection systems.
Land Mine Neutralization	Demonstrate off route smart mine clearance capability to neutralized top and side attack mines. Integrate a ground based detection with standoff neutralization technology.	Demonstrate an explosive/kinetic neutralization system in a ground vehicle. Demonstrate RF technology to detect electronically fuzed mines from a standoff distance. Develop a chemical neutralization system that will provide for non-explosive means to neutralize mines. Demonstrate the enhanced area explosives capability.	Demonstrate the applications of laser directed energy for mine neutralization. This effort will be evaluated for incorporation into an electronic beam neutralization system in FY08.

Application/Mission	Short-term (1-2 Years)	Mid-term (3-5 Years)	Long-term (6+ Years)
MIW Surveillance.	Baselining & exploitation of current mapping, survey, & intelligence capabilities & products for MIW.	Intermittent surveillance of mining activities. Tactical awareness of enemy & environment.	Continuous, fused all source I&W of mining activity.
Mine Reconnaissance.	Factor of 7 improvements in VW clandestine recon including buried mines. 6 snmi/hr search rate for deep water/SW mines.	Rapid reconnaissance (80snmi/hr) of surf zone to craft landing zone.	Autonomous multi-platform clandestine reconnaisance/ kill capability.
Clearance.	In-stride mine clearances (<2 hrs) of assault lanes (surf zone to beach zone). Rapid target sweeping of shallow and VSW influence mines.	In-stride clearances of sea mines in VSW, shallow water.	In-stride clearance of combined mines and obstacle fields (surf zone and CLS).
C^4I	End-to-end simulation of all MIW operations.	Distributed interactive simulation. MIW integrated into Expeditionary Warfare.	
Mining	Long range detection of surface & submerged targets in 20-600 ft water.	Over the Horizon underwater mine IFF. Remote command capability.	Autonomous sensor netting minefield. Pressure influence detection of slow targets in high wave bkgd.

3.5.2.2 Major Technical Challenges. The major technical challenges for land and sea mines include the ability to develop multi-sensors and signal processing techniques to accurately track and locate target vehicles and vessels. Challenges for countermine include sensors development to differentiate mines from clutter in various soil, foliage, and terrain types; develop sensor fusion techniques and automatic target recognition algorithms for autonomous mine localization and identification; development of standoff neutralization technologies using directed energy or area explosives and integration of these technologies into a single platform; and using affordable, autonomous robotics systems to conduct minefield breaching and obstacle clearance operations. For the countermine protection kits: designing effective components that are lightweight, easy to install and do not significantly add weight or degrade the performance of the equipment. Sea mine countermeasure challenges include: low-cost high-performance sensors, data fusion, and process for high probability detection and discrimination of underwater mines from environmental clutter in water column or buried in the ocean bed;

reliable targeting and destruction of sea mines located in water depths compatible with LIDAR imaging ranges; accurate and stable delivery of large distributed explosive arrays at extended standoff ranges; development of compact light weight acoustic and magnetic signal sources for influence mine sweeping from small, shallow water craft; and in-stride, remotely-deployed obstacle breaching capability against mixed anti-invasion mine and obstacle fields in the surf and beach zones. The major EOD challenges include developing low cost robotics platforms and controls and extending capabilities of magnetic and inductance sensors to detect buried UXO.

3.5.2.3 Related Federal and Private Sector Efforts. Mine and countermine technologies are primarily developed for military applications. DOE and EPA test range clearing and dump site remediation efforts require Mine, Countermine, Demining, and EOD technologies. Sandia National Laboratory (DOE) conducts a Sea Mine Countermeasures project with Navy coordination under a DOE/DoD Memorandum of Understanding (MOU).

3.5.3 Mines & Countermines Investment Strategy

3.5.3.1 Technology Demonstrations. The technology demonstration entailed in Mines and Countermines include the demonstrations in Mines, Humanitarian Demining and Joint Countermine technology areas.

Intelligent Minefield (IMF) ATD. DTO WE.02.07.AN. The IMF ATD will internet Wide Area Munitions (WAMs) and advanced acoustic sensors into an autonomous anti-armor/anti-vehicle system to increase the WAM minefield effectiveness by 50%.

Humanitarian Demining. Congress provided money and language directing the Army to develop technologies for mine detection, classification, mapping, and neutralization for use in humanitarian demining and in military Operations Other Than War (OOTW). The Army technology based in partnership with private industry and the operational user (CINC demining staffs) will integrate and demonstrate Commercial-Off-The-Shelf (COTS) technology. Coordination with CINC demining representatives indicate an immediate need for short term, low technology solutions. This program will integrate basic low risk tools, items and kits that improve efficiency and safety for US demining trainers and solutions that leverage previous and ongoing Countermine programs without duplication of effort. Additionally, the program will leverage the ongoing Countermine program both to integrate technologies previously identified in the Countermine exploratory development program and serve as a spring board for fielded Countermine equipment (e.g., hand held detectors) to meet the need to increase safety, quality control, and speed.

Joint Countermine. JWCO DTOG01-10. The overall Countermine objective is to provide a seamless mine/minefield detection and neutralization capability in a force projection that comes from deep water through littoral regions to land. Joint countermine encapsulates the following demonstrations which are described in the Joint Warfighting Science and Technology Plan (JWSTP). In addition to these demonstration descriptions, the JWSTP Contain roadmaps and funding to further describe these Joint Countermine efforts.

- Close-In Man Portable Mine Detector Program (CIMMD)

- Vehicle Mounted Mine Detector (VMMD)
- Mine Hunter Killer (MHK)
- Anti-Helicopter Mine Countermeasure (AHMCM)
- Mine Countermeasures Integration and Automation (MCMIA)
- Hyperspectral/Multi-Sensor Mine Detection
- Advanced Lightweight Influence Sweep System (ALISS)
- Explosive Neutralization Technology Demonstration (EN ATD)
- Rapid Airborne Mine Clearance System (RAMICS)
- Focused Shock Wave Neutralizer
- Littoral Remote Sensing
- Advanced Minehunting Sensors
- Combined Zone Mine/Obstacles Breaching

3.5.3.2 Technology Development. Technology development efforts support demonstrations described above, to lay the foundation for demonstrations and address long-term military applications. Major task areas are:

- Sea mines to develop viable sensor technologies for a coastal region "Littoral Sea Mine" capable of providing detection and fire control tracking of quiet submarines and surface ships. Technology issues include underwater signaling and communications, as well as underwater sensors (magnetic, acoustic, electric field, and pressure) for sea vessel detection/tracking.
- Land countermines to develop detection of non-metallic and metallic mines, neutralization of on and off route mines, autonomous operations, and area clearance of land and beach zones. Countermines Protection Kit (CPK) to utilize advances in military vehicle armor, commercial energy absorbing materials to design add-on components that will increase vehicle and personnel survivability.
- Sea Countermeasures to develop high rate (50 square mile/hour and aerial standoff of 1000 ft) of mine surveillance and reconnaissance, hunting and in-stride mine clearance.
- Humantarian demining to develop and demonstrate the capability to detect and neutralize land mines, tactics and training media for humanitarian demining missions.
- EOD develops techniques to render safe large numbers of submunitions, neutralization of underwater ordnance, and detection of buried unexploded ordnance.

3.5.3.3 Basic Research. Basic research related to mines and countermines include physics based research relating to acoustic, seismic, multispectral/hyerspectral, laser and infrared sensors development; signal processing; and neural net integration. Similar statistical techniques and modeling are being pursued for sensor fusion and autonomous detection and neutralization. In addition explosive, kinetic and direct energy techniques are also being explored to address the need for advanced neutralization systems. Basic research related to sea mines and mine countermeasures include the broad areas of ocean, environmental/acoustic/optic/electromagnetic and atmospheric modeling.

3.6 CW—Tactical Propulsion

3.6.1 Warfighting Needs

The DoD requires payload increases over current systems of 25% by FY05 and 100% by FY10. Increased payload capability can be directly traded for increased range and decreased time-to-target. Technology advances in divert propulsion systems will be available to demonstrate a reduction in the number of theater missile defense systems to cover a given area by 26% (FY00) and 60% (FY10). Potential transitions include Army and Navy tactical missions, Air Combat Command and several space missions within Air Force Space Command.

3.6.2 Overview

3.6.2.1 Goals and Timeframes.

Application/Mission	Short-term (1-2 Years)	Mid-term (3-5 Years)	Long-term (6+ Years)
Agile Propulsion for short & medium range Anti-Air Missions.	Low-cost TVC nozzle feasibility demo. Minimum signature CL-20 propellant (Isp 248s) motor performance demo. Demo of gelled liquid propellant flt wt engine.	Low-cost integrated aero/ TVC composite case motor demo. Demo of high P_C (4000 psi) combustion of CL-20 propellant.	Clean ADN propellant (Isp 252s) motor performance demo.

Application/Mission	Short-term (1-2 Years)	Mid-term (3-5 Years)	Long-term (6+ Years)
Standoff Propulsion for medium & long rang Anti-Air/Surface Missions.	Performance demo of Low Cost Missile inlet and combustor components. Ground test of valveless/ throttable ducted rocket. Ground test of flt wt GAP ducted rocket. Ground test of variable-flow ducted rocket. Ground test of Low Drag Ramjet having bent body combustor.	Motor performance demo of metallized CL-20 propellant (Isp 272s). Demo of high stiffness, low weight composite case. Flight demo of Low Cost Missile RJ system (M>3).	Demo of low cost/erosion, carbon-carbon material for nozzle throats. Demo of efficient, low erosion fiber or cloth-reinforced insulation material. Freejet demo of hydrocarbon fueled scramjet (Isp 850s; thrust 60 lbf/ lbm/s at M8).
Gun-Launched Propulsion for Surface Fire Support.	Demo propellant ballistics (Pc 5-8k psi; n< 0.6). Feasibility demo of lt wt, low volume wrap around fins.	Gun-launched flight test of prototype motor (high Pc, composite case, wrapped around fins) to demo performance (range > 3.5nmi). IM tests of prototype motor.	

3.6.2.2 Major Technical Challenges. The Integrated High Performance Rocket Propulsion Technology (IHPRPT) program plan focuses on future tactical rocket propulsion requirements. The goals this program addresses are increased delivered energy and mass fraction while reducing sensitivity (insensitive munitions) to unplanned hazard stimuli. The challenges lie in increasing propellant energy and density without increasing sensitivity, improving inert propulsion materials strength-to-weight/volume ratios, and reducing erosion and weight of insulation and nozzle materials. IHPTET is the program plan by which future tactical airbreathing propulsion requirements will be achieved. The goals this program addresses are improving specific fuel consumption, increasing thrust/unit airflow, increasing combustor/inlet temperature, and reducing cost. The challenges lie in high combustion efficiencies, reduced erosion and weight of combustor insulation, elimination or reduction to acceptable levels ramjet combustor oscillations, and increasing the performance and reducing the size of ramjet components.

3.6.2.3 Related Federal and Private Sector Efforts. DoD and industry have efforts in propulsion technology. Also, NASA has efforts in propulsion technology for space and orbit transfer, some of which are translatable to tactical propulsion as is tactical technology to their area of interest. Industry IR&D investment in FY95 was approximately $55M. Further, these efforts are focused through the Joint Army, Navy, NASA, and Airforce (JANNAF). IHPRPT and IHPTET are highly coordinated and integrated efforts with all Services, NASA and industry.

3.6.3 Investment Strategy

3.6.3.1 Technology Demonstrations. Tactical propulsion technology demonstrations include those that support the DTO's:

- Missile Agility/Kinematic Enhancement (MAKE) (WE.01)
- Future Missile Technology Integration (FMTI) [Formerly TACAWS] (WE.07)
- Low Cost Missile ATD (WE.15)
- Anti-jam GPS/Inertial Competent Munitions (WE.12)
- Low Cost Precision Kill (LCPK) 2.75 Anti-Air ATD (WE.28)
- Ducted Rocket TD

3.6.3.2 Technology Development. Technology development efforts support demonstrations described above by providing the foundation for the demonstrations and by addressing longer-term military applications needs/requirements. Major task areas are:

- Solid propellant formulation with emphasis on increased specific and density impulse, high strength mechanical properties, acceptable burning rate properties at high pressure, and environment-compatibility while maintaining low sensitivity.
- Gelled liquid propellant engine development.
- High strength to weight/volume composite case development having acceptable attachments.
- Fiber-reinforced, low erosion/heat-conductivity/density insulation material development that has low lot-to-lot variability.
- Development of low cost process for fabricating low erosion, carbon-carbon nozzles and nozzle inserts.
- Low cost, compact Thrust Vector Control (TVC) nozzle system development.
- Variable thrust ducted rocket development.
- Development of high-performance inlets/combustors/fuel management for integration into hypersonic and supersonic ramjet systems.

3.6.3.3 Basic Research. Of special interest to the propulsion community are quantum chemistry, synthesis of energetic materials, combustion mechanisms, and flow structures in combustors.

3.7 CW—Warheads & Explosives

3.7.1 Warfighting Needs

The DoD requires improvement over existing systems; 1) aimable warheads in new/upgraded air-surface missiles which provide increase in kill probability to one and will reduce requirements for missiles by 20-30%; 2) adaptable warheads that are more lethal and resistant to modern countermeasures and reduce munitions inventory requirements by 30-40%; 3) penetrating weapons that have 300% greater penetration capability, and destroy 50% more hard targets; 4) multi-mode torpedo warheads with the capability to defeat Rest of World ASW, ASUW, and SSTD threats targets, Direct Fire Munitions lethal against fielded and projected armors thereby enhancing battlefield exchange ratios by a factor 2-4. Potential transitions include AIM-9X, Standard Missile, TOMAHAWK, AMRAAM, Patriot, STAFF P^2I, JAVELIN, TOW follow-on, M829, RAM, F-22, JAST, JASM, SSTD, and LHT.

3.7.2 Overview

3.7.2.1 Goals and Timeframes. The major goals for "Warheads & Explosives" are to provide improvements in weapon lethality, multi-mission flexibility, survivability, and reduced cost. Goals are:

Application/Mission	Short-term (1-2 Years)	Mid-term (3-5 Years)	Long-term (6+ Years)
Defeat of Advanced Undersea threats.	Feasibility to exploit bubble for a crown attack on a bottomed submarine.	Common explosive for multimode warheads.	Layered/ring/gradient explosives. Compressed flux magnetic generator. Neutralize the advantage of the double-hulled submarine.
Defeat weapons of mass destruction in storage, production, and in the field.	Evaluate chemical & thermal defeat mechanism and quantify performance.	Demo interim capability in prototype (BLU-109M) 2000lb warhead.	Expand lethal mechanism to harder and more diverse target spectrum.
Defeat advanced armor and armor protection systems.	Defeat explosive reactive armor in integrated 120mm KE cartridge.	Demo long EFP in 120mm STAFF weapons system.	Demo 300% increase in probability of kill in dynamic armor engagement scenarios.
Expand lethality and operational envelope of undersea warheads and explosives.	Demo 150% increase in bubble energy of underwater explosive.	Demo multi-mode torpedo warhead for spectrum of undersea threats.	Reduce warhead weight & volume to extend range & reduce time to impact of advanced torpedo.

Application/Mission	Short-term (1-2 Years)	Mid-term (3-5 Years)	Long-term (6+ Years)
Defeat hardened C^3 and countermeasured buried targets.	Double penetration capability of BLU-109.	Boost penetration velocity using external propulsion, increase penetration depth 300%.	Introduce advanced high energy density explosives into hard target hypersonic penetrators.
Defeat spectrum of air/ surface threats using target adaptable warheads, advanced explosives, and hypervelocity missiles for time critical targets.	Conduct flight test of multi-mode warhead and sub-munition. Quality advanced explosive for aimable war-head.	Demo miniature munition (250lb) with anti-jam GPS and LADAR guidance. Demo terminal performance of low-cost missile.	Demo next generation of adaptable warheads capable of expanding target spectrum and range of missions.

3.7.2.2 Major Technical Challenges. Warheads and Explosives challenges include insensitive explosives with enhanced performance; quantification of very high velocity penetrator performance; and development of material property models for adaptable warhead designs. Increased lethality undersea weapon warheads challenges are to enhance the probability of kill by development of higher bubble energy and shock explosive formulations and development of shaped charges using explosively driven compressed magnetic flux generator.

3.7.2.3 Related Federal and Private Sector Efforts. DOE explosives technology efforts are integrated with DoD efforts.

3.7.3 Investment Strategy

3.7.3.1 Technology Demonstrations. Warheads and explosives demonstrations supporting the DTOs:

- Advanced Unitary Penetrator (AUP) (WE.11)
- Counter Active Protection Systems (CAPS) (WE.13)
- Anti-Material Warhead Flight Test (AWFT) (WE.05)
- Miniaturized Munition Technology (MMT) Flight Test (WE.08)
- Direct Fire Lethality (WE.18)

Additional technology demonstrations include:

Boosted Penetrator. This Critical Experiment will demonstrate by FY00, the warhead technology that will facilitate the fielding of a compact, precision guided weapon that has the high impact velocity necessary to defeat a wide range of heavily hardened and/or deeply buried targets.

Ordnance Program was funded to demonstrate concepts that defeat weapons of mass destruction. The demonstration includes a flight testing of prototype systems. The project is expected to take 3 years and cost about $15M. The prototype (a modified

BLU-109 Warhead) will incorporate advancements in Warhead/Lethal Mechanisms, Fuzing, Damage Assessment, and Guidance and Control.

3.7.3.2 Technology Development. Technology development efforts support demonstrations described above, to lay the foundation for success and address longer-term military applications. Major task areas are:

Missile Warheads - Addresses technologies needed to enhance anti-air and anti-surface missile performance against all air and surface targets with the exception of armored. Critical areas include adaptable warhead technology and defeat cruise missiles.

Torpedo Warheads - Covers Navy unique technology areas specifically directed towards advanced torpedo performance improvements, including new warhead concepts, explosives, materials, and both warhead design and target damage prediction tools.

Hard Target Penetration - Covers technologies specifically directed toward warheads needed for use against a variety of targets and structures buried in earth or concrete, including large extremely hard, multi-level underground facilities and facilities for storage and production of weapons of mass destruction.

Anti-Armor - Covers exploration of novel concepts, liner materials, initiation techniques, and more powerful insensitive explosives directed specifically toward defeat of armored targets. Integrates technologies into practical anti-armor configurations and demonstrates designs against advanced armors and countermeasures.

Advanced High Explosives - Covers generic technology areas needed to improve performance characteristics of explosives that have benefits and spin-offs for use in a broad range of applications.

3.7.3.3 Basic Research. Research in mechanics is focused on gun propulsion, missile/projectile aerodynamics, mechanics of armor/anti-armor materials, explosives, and weapons system structures. These research areas are all critical for improving the performance of our weapons systems.

3.8 DEW—Laser

3.8.1 Warfighter Needs

The DoD requires improved or new capabilities in strategic and tactical missile defense, cruise missile defense, satellite negation, high resolution imagery, air defense, ship defense, ground combat and close support, and aircraft self-protection. All of these requirements can be addressed by laser weapon systems. Laser and optical system technology offers the potential for a paradigm shift in weapon systems for the 21st century:

- Long range, speed-of-light delivery to target
- Graduated engagements, from disrupt to destroy
- Surgical – minimum collateral damage, low fratricide
- Multiple, low-cost shots – large number of kills per platform
- All-aspect engagements – unconstrained by kinematics or gravity

- Synergism with high resolution optical sensing – imaging, surveillance, standoff detection

These advantages will provide dramatic improvements in current weapon capabilities and enable new missions which are not currently possible. In the near to mid-term, this includes transition of semiconductor laser technology to non-lethal weapons (illumination, designation, dazzling) and medical laser applications. In the long term, potential new weapon capabilities include the Airborne Laser (ABL) for boost phase negation of theater and cruise missiles at long range; Ground-Based Laser (GBL) for negation of Low Earth Orbit (LEO) satellites; Space-Based Laser (SBL) for theater/national missile defense, Anti Satellite (ASAT), and surveillance; moderate-power laser systems for robust infrared countermeasures; passive and active laser/optical systems for remote sensing/standoff detection; laser weapons for anti-ship missile defense; and laser weapons for platform/base self-protection and offensive capabilities in tactical engagements.

3.8.2 Overview

3.8.2.1 Goals and Timeframes. Technology development and demonstration efforts are oriented to establish a mature and comprehensive technology basis to support laser weapon systems development decisions. In many cases, this requires an integrated demonstration of laser and optical technology components and subsystems. Major goals and associated time frames include the following:

Application/Mission	Short-term (1-2 years)	Mid-term (3-5 years)	Long-term (6+ years)
Airborne Laser (ABL) for boost-phase negation of theater missiles at long range (up to 600 km).	COIL device, atmospheric measurements, adaptive optics, and beam control technology to support ABL demonstrator development.	Demo adaptive optics and beam control technology to assure ABL design meets operational performance requirements.	Advanced COIL, adaptive optics, and beam control technology to provide 20-30% increase in ABL operational range.
Ground-Based Laser (GBL) for negation of LEO satellites.	COIL device technology at baseline levels; feasibility demos of adaptive optics for atmospheric compensation and active satellite tracking.	Integrated beam control demo – fullscale demo of weapons-class performance for all atmospheric compen-sation and beam control functions.	Advanced COIL, adaptive optics, and beam control technology to support design optimization and performance growth for GBL ASAT system development.
Space-Based Laser (SBL) for TMD, NMD, ASAT, air defense, surveillance, air superiority above the clouds.	Integrated ground performance demo at HPW-class HF chemical laser, 4-meter segmented telescope, out-going wave-front control.	Demonstrated acquisition, tracking technology. Preliminary ground demo of prototype SBL system.	Integrated SBL space demo of missile-killing system

Application/Mission	Short-term (1-2 years)	Mid-term (3-5 years)	Long-term (6+ years)
Laser system for IR countermeasures, based on damage/destroy mechanisms.		Establish vulnerability of target set; demo laser device feasibility and scaling for selected wavelength.	Ground demo of integrated laser system performance against IR-guided missile HW in realistic scenarios.
Laser weapons for anti-ship missile defense.	Evaluate target lethality & utility of various laser concepts for ASMD. Demo 1 kW FEL.		
Semiconductor/solid-state laser sources and integrated beam control.	Transition semiconductor laser technology to non-lethal and medical applications.	Demo architecture for scaleable, coherent semi- conductor laser diode arrays; demo concept for electronic beam steering.	Demo coherent array scaling to moderate and high power; establish feasibility of conformal arrays and integrated laser source/beam control.

3.8.2.2 Major Technical Challenges. For laser devices, the major technical challenges are increasing laser device efficiency and reducing system size and weight to meet platform constraints and scaling to high power while maintaining good beam quality. For some applications, the laser device must also operate at a specific wavelength or in a particular wavelength band. Major technical challenges for beam control include 1) development and demonstration of adaptive optics hardware to compensate for distortions in the beam train and in propagation to the target; 2) application of laser beacon concepts to sense distortions caused by atmospheric turbulence; 3) rejection of high-bandwidth jitter induced by platform and atmospheric turbulence; 4) compensation for tilt anisoplanatism; 5) active tracking and illuminator/target effects; 6) aimpoint designation and maintenance; and 7) overall beam control system integration and performance evaluation. In the area of laser effects, the major technical challenge is to determine the materials, configuration, functional characteristics, and vulnerability of potential targets. A second challenge is development of modeling and simulation tools to determine weapon system effectiveness. Another challenge is to establish accurate safety thresholds for the protection of personnel.

3.8.2.3 Related Federal and Private Sector Efforts. DoD organizations have primary responsibility for development and application of high power laser technology. However, there is some complementary activity within DOE and industry. Lawrence Livermore and Sandia National Laboratories have laser source development and some beam control programs, with emphasis on laser fusion (Livermore) and power beaming (Sandia) applications. As a direct spin-off of DoD research, the civilian astronomy community has embraced adaptive optics and laser beacon sensing technology to improve resolution of ground-based telescopes by compensating for distortions introduced by atmospheric turbulence.

3.8.3 S&T Investment Strategy

3.8.3.1 Technology Demonstrations. Laser DEW technology development encompasses several demonstrations, intended to establish a level of technology maturity

which supports transition to systems development programs. Major demonstrations support three DTOs:

- Airborne Laser (ABL) Technology Demonstration (WE.04)
- Space-Based Laser (SBL) Technology Demonstration (WE.04)
- Ground-Based Laser (GBL) Integrated Beam Control Demonstration (WE.10)
- Infrared Countermeasures (IRCM) Demonstration (WE.19)
- Laser Diode Array Demonstration (WE.19)

3.8.3.2 Technology Development. Technology development efforts complement the technology demonstration efforts described above to fully support laser weapons system development decisions and lay the foundations for future demonstration efforts to address longer-term military applications and capabilities. Major task areas include:

- Chemical Oxygen Iodine Laser (COIL) device technology, with emphasis on improved efficiency and lightweight designs to reduce system weight and improve operational suitability.
- Advanced laser technology, considering new lasing concepts and target interaction phenomenology with the potential to further improve laser power per unit weight and overall military effectiveness.
- Non-linear optics technology, with the potential to produce frequency-agile laser sources and, by phase conjugation, to automatically correct for phase distortions in an optical train or propagation path for both laser propagation and imaging applications.
- Passive and active high-resolution imaging technology, including concepts for image reconstruction, real-time processing, and aperture synthesis, both to support laser weapon functions (target verification, aimpoint designation and maintenance, damage assessment) and to provide situational awareness in both terrestrial and Earth-orbit (out to geosynchronous altitudes) arenas.
- Target vulnerability assessment efforts, to include target model development, analytical vulnerability assessments, experimental testing and assessment validation, and military effectiveness analysis.
- High power optical components, to provide optical coatings, mirrors, windows, and other specialized optical components which can operate and endure in a high power laser beam train without inducing significant distortion or loss.
- Technology and experiments to understand and characterize the atmospheric propagation environment, including turbulence effects over extended

propagation paths and organized structures in turbulent flow fields such as boundary layers.

- Experiments and modeling to establish accurate safety thresholds for personnel protection.

3.8.3.3 Basic Research. Basic research efforts for high power lasers emphasize the fundamental understanding of the limitations of laser technology and its application, and investigation of promising new approaches and concepts. Efforts are conducted in advanced laser concepts, nonlinear optics, optical image sensing and reconstruction, optical tomography of turbulent flow fields, and advanced concepts for adaptive optics and laser beacon sensing.

3.9 DEW—High Power Microwave (HPM)

3.9.1 Warfighter Needs

The DoD requires improved capabilities in countering artillery fire, ship defense against cruise missiles, aircraft self-protection, suppression of enemy integrated air defense systems, space control, security, counter-proliferation, and disruption or destruction of command and control assets. All of these requirements can be addressed by HPM weapon systems which upset or damage the electronics within the target. HPM weapons offer military commanders the option of:

- Speed-of-light, all-weather attack of enemy electronic systems.
- Area coverage of multiple targets with minimal prior information on threat characteristics.
- Surgical strike (damage, disrupt, degrade) at selected levels of combat.
- Minimum collateral damage in politically sensitive environments.
- Simplified pointing and tracking.
- Deep magazines and low operating costs.

Coordinated Army, Navy, Air Force and DNA HPM transition plans are focused on demonstrations of mission-oriented concepts: aircraft self protection, anti-ship missile defense, and counter munitions (EW Electronic Attack - degrade/neutralize enemy defenses); and lethal Suppression of Enemy Air Defenses (SEAD) and C2W/IW (Precision Force, MOUT, and IW). Potential Warfighter payoffs include generic protection against a wide variety of missile/munition threats (IR, EO, RF, laser-guided), improved effectiveness and lower attrition rates of friendly systems, and negation (permanent damage, long-term disruption, and temporary degradation) of enemy command, control, and general information systems. Finally, electronic protection techniques developed under the HPM program are being continuously transitioned to users in order to harden US systems against hostile HPM weapons or inadvertent EMI/EMC. Joint development and test projects demonstrate the maximization of investments to meet individual Service/Agency mission requirements.

3.9.2 Overview

3.9.2.1 Goals and Timeframes. Technology development and demonstration efforts are oriented to establish a mature and comprehensive technology basis to support microwave weapon systems development decisions. In many cases, this requires an integrated demonstration of microwave source, pulsed power and antenna subsystems. Major goals and associated time frames include the following:

Application/Mission	Short-term (1-2 years)	Mid-term (3-5 years)	Long-term (6+ years)
HPM System for Point Defense.	Demo of compact, high-power UWB source. Demo of high average power narrowband source.	Live fire cable-car demo. Field demo of high average power narrowband source.	Ship-self-defense demo, Countermunition demo.
HPM System for C2W/IW.	Effects assessments.	Field demo.	Airborne demo.
HPM System for SEAD.	Demo of compact, high-power narrowband source.	Explosively-driven single pulse device demo.	Multiple-pulse device demo.
HPM System for Space Control.	Effects assessments.	Modeling and simulation for concept development.	Field demo.

3.9.2.2 Major Technical Challenges. The major technical challenges for HPM weapons include developing and demonstrating:

- Compact, high peak power and/or high average power HPM sources.
- Compact, high gain, ultra-wideband (UWB) antennas.
- Compact, efficient, high power, pulse power drivers.
- Predictive models for HPM effects and lethality.
- Low impact hardening of systems against hostile and self-induced EMI.
- Reliable and affordable system integration meeting military platform requirements.

3.9.2.3 Related Federal and Private Sector Efforts. DoD organizations have primary responsibility for the development and applications of HPM technology. However, both DOE and private sector efforts complement military HPM programs. Lawrence Livermore, Los Alamos, and Sandia National Laboratories have HPM source development and effects programs which directly support Service efforts, while the private sector has evolved both independent and cooperative RF effects programs. CRDAs have been initiated to develop and transition improved techniques for measuring electromagnetic interference. The electronics industry as a whole is working closely with the Services to ensure compliance with new international standards for electromagnetic protection.

3.9.3 S&T Investment Strategy

In executing the DoD HPM Program, focus is maintained on specific technology demonstrations, in order that the technology effort at the component level can also be focused. DoD investments among the various technology demonstration and technology development efforts are allocated in accordance with their potential payoff to warfighting needs and their relative contribution to achieving the HPM goals.

3.9.3.1 Technology Demonstrations. HPM weapons encompass a number of technology demonstrations in the field. Major demonstrations support two DTOs:

- Aircraft Self Protection Demonstration (WE.19)
- Command and Control Warfare/Information Warfare Demonstration (WE.22)
- Suppression of Enemy Air Defenses (SEAD) Demonstration (WE.22)

3.9.3.2 Technology Development. Coordinated Army, Navy, Air Force, and DNA HPM technology developments are subdivided into a number of major constituent areas, these include:

- Compact, High Power HPM Sources: Includes fourfold increase in UWB output power, six-fold increase in narrow band pulse length, and narrowband tunability up to an octave. Weight should be ~500 lbs and volume ~1.5 cu ft (exclusive of antenna and pulse power).
- Compact, High Power, High Gain, Ultra-Wideband Antennas: Requires reduction to 18 inch antenna diameter with approximately 15 - 20 dB of antenna gain.
- Compact, Efficient, High Power Pulse Power Drivers: Primary challenge is to develop compact (~500 lbs in less than 10 cu ft), high peak power (>50 GW) packages.
- HPM Effects and Lethality: Includes RF testing of a wide range of air, sea, land, and space military assets; RF effects database development; reliable prediction of RF effects to permit extrapolation to other systems, development of innovative countermeasure techniques and incorporation of HPM into accepted military weapon engagement models. Also includes assessment of biological effects necessary to establish safety thresholds for personnel protection.
- Systems Integration Meeting Military Platform Requirements: Encompasses integrating pulse power drivers, HPM sources, and output antennas into military platforms such as fixed-wing and rotary aircraft, naval combatants, land vehicles, aircraft pods, unmanned aerial vehicles and munitions.
- Low Impact Hardening of Systems Against Hostile and Self-Induced EMI: Includes transitioning EM hardening to users in response to existing EMI/EMC problems and projected threats; identifying susceptibilities in US

air, land, sea and space militarily critical systems; and developing hardening countermeasures which minimally impact system performance, cost or maintainability.

- Evaluation of Additional Applications: Based on effects assessments and technology development efforts, evaluations are being performed to identify additional militarily useful applications. Applications under consideration include: ASMD, counter-proliferation, counter-munition, and space control. These evaluations will lead, where appropriate, to additional technology demonstrations.

3.9.3.3 Basic Research. Basic research efforts for high power microwaves emphasize the fundamental understanding of the limitations of microwave technology and its application, and investigation of promising new approaches and concepts. Efforts are conducted in RF sources, antennas, and pulsed power systems and in RF effects phenomenology.

3.10 EW—Threat Warning

3.10.1 Warfighting Needs

The warfighter needs to know, unambiguously and in real-time, the total threat situation ("picture") which endangers successful completion of the operational mission—whether the warfighter is at the battlespace command level, or in the single-seat cockpit. For optimal response in a threat environment—whether avoidance, ECM, lethal, maneuver or in combination—the warfighter needs to positively know the threat is present, its parameters, location(s) and intentions *in time* to invoke that response. The S&T in this Threat Warning subarea will produce advanced receiver, processor, antenna and software (SW) algorithm technologies that directly address these issues. On a component level, circuit miniaturization and digital trends will yield affordable receivers which are lighter, smaller, more reliable and power efficient. Planned improvements in receiver/processor performance, commercial-off-the-shelf (COTS) and open adaptive, real-time symmetric multi-processing (RTSMP) architectures will provide faster threat detection and recognition, and increased ability to decipher multiple, simultaneous, complex-modulation signals. Digital receivers incorporating these processor advantages will allow rapid reconfiguration of the receiver at the unit level through SW updates, vice expensive and time consuming hardware (HW) changes. Advanced location algorithm developments, coupled with antenna/apertures more accurate in angular threat determination and advances in sensor information fusion techniques, will provide unambiguous resolution of the threat environment ("situation awareness"), thereby allowing the warfighter to select the most appropriate response. Threat Warning technology has multiple opportunities to make Tri-Service transitions into combat systems with RF and/or electro-optic (EO)/IR receivers.

3.10.2 Overview

3.10.2.1 Goals and Timeframe. The primary focus of this subarea is to provide the warfighter the ability to locate, detect, identify, track and classify potential systems at

long range with high-accuracy. These systems include receivers, processors and signal analysis algorithms which will provide adequate time to respond with the appropriate countermeasures. Major goals and associated timeframes include:

Application/Mission	Short-term (1-2 Years)	Mid-term (3-5 Years)	Long-term (6+ Years)
Improved threat emitter location and combat ID.	Dev and demo integrated HW/with multiple SW algorithms to perform real-time threat ID and location.	Dev and demo highly stable RF receiver, digitizer, processor and SW to detect and track threat parametrics.	Dev and demo integration of precision location/ID with offensive targeting cues to yield subdegree threat geo-location.
	Single aperture, hemi-spherical 2° DF flight demo.	Dev EO sensor and fiber optic technology to detect, ID and localize laser based threats.	
Low latency receiver processor throughput and fusion of off-board data.		Dev techniques for fusion with RF sensors to improve capability to detect and classify threats.	Dev and demo full real-time information in the cockpit (RTIC), automatic response reasoning and real-time "out" of the cockpit (RTOC) capabilities.
Common digital receiver architecture and significant size reduction.	Dev and demo an EW receiver fabricated entirely from MMIC for aircraft, ships and other platforms.	Dev and demo a wideband, digital receiver for EW applications to be used onboard aircraft and ships.	Dev and demo DSP & fiber optic integration with RTSMP directly behind intercept apertures.
World wide merchant ship tracking.	Specific emitter identification (SEI) equipment on board at least one platform in all major theaters.	Dev and demo combat ID using SEI technology.	Dev weapons embedded SEI.

3.10.2.2 Major Technical Challenges. Development of a high-accuracy direction finding (DF) capability featuring the amplitude-only DF and low cost time difference of arrival concepts requires close-tolerance, phase-tracked receiver components and low signal threshold detection. Development of functional elements using microwave monolithic integrated circuits (MMIC) chips is the major technical challenge for an all MMIC EW receivers. The complex task of assembling a digital RF receiver involves the development and integration of high speed, high resolution digitizers and high throughput digital processing for spectral analysis and dynamic range extension. To achieve real-time threat identification and location includes pulse-level SEI extraction, processing and automation. In order to develop a highly stable RF receiver for detection and tracking of hostile emissions requires expanded processing bandwidth and dynamic range for environment characterization. In the area of EO/IR, the major technical issues are to increase the detection range of existing sensors by 100%;

improve their angle-of-arrival determination to better than one degree; enhance probability of detection to over 95%; and reduce false alarms to less than one per hour. The EO technology, challenges include increasing sensor sensitivity and dynamic range, provide angle-of-arrival information for CM cueing, and increasing the detection bandwidth to encompass the aforementioned laser threats. Threat identification and off-axis detection require component/processing improvements.

3.10.2.3 Related Federal and Private Sector Efforts. Digital receiver and COTS processor technologies have both private and federal applications. However, the EW sector demands are higher, with requirements for wider bandwidth, faster tuning, more instantaneous dynamic range and high probability of signal detection. EW-related investments here focus on military needs not met by the commercial sector vis-a-vis computer architectures and digital signal processing (DSP).

3.10.3 S&T Investment Strategy

In executing the Threat Warning subarea, focus is maintained on specific technology demonstrations which synergistically integrate advanced aperture, processor, receiver and SW technologies (in specific combinations), in order that technology development in these same areas—but at the component/functional level—can also be focused. National investments among the various technology demonstration and technology development efforts are allocated in accordance with their potential payoff to warfighting needs, affordability and their relative contribution to achieving Threat Warning goals.

3.10.3.1 Technology Demonstrations. Threat Warning encompasses multiple “tech demo” level efforts, concentrating in the areas of precise ID and geo-location of threat emitters in real time, fusion of on-board sensor information with off-board theater asset information to produce coherent Situation Assessment (SA), and integrated multi-spectral ES/warning with multi-spectral EA/ECM response (WE.24). Key to the Joint warfighter critical area of Dominant Battlespace Knowledge will be the efforts demonstrating RTIC and, in the reverse path, RTOC. By tieing the multi-functional EW sensors into the “digital” battlefield/ battlespace, all air and surface platforms and joint command operation centers will have situational awareness for subsequent targeting, battle damage assessment and mission planning.

3.10.3.2 Technology Development. The Service efforts in the Threat Warning subarea can be divided into three classes and support the tech demonstrations identified above:

RF Technology - Develop advanced RWR low signal detection and rapid parametric conversion capabilities with MMIC, fiber optic/opto-electronic and digital technologies. Provide highly stable receivers, digitizers, processors and software. For affordability, emphasis is placed upon COTS processor, and open/scaleable architectures.

IR/Ultraviolet (UV) Technology - Develop IR/RF warning sensor fusion; multi “color” IR band energy detection schemes; high angular resolution/gimbal-less apertures; active, laser-based detection techniques; missile signature model validation; and algorithms to detect low level signatures in a low-noise/high clutter background.

EO Technology - Develop laser warning technologies usable on high performance aircraft to provide warning from the short range nature of laser designator, range finder and beamrider threats.

3.10.3.3 Basic Research. Basic research initiatives which contribute to this subarea include: advanced semiconductor/opto-electronic materials and sub-micron processes (for faster, efficient, affordable DSP devices, and uncooled EO/IR focal plane arrays); advanced machine reasoning (e.g., "artificial intelligence"; and advanced electromagnetics/antenna principles for broadband, low signature, coherent curved/planar/distributed apertures).

3.11 EW—Self Protection

3.11.1 Warfighter Needs

The warfighter has a mission to accomplish and faced with a threat environment dominated by more complex and robust weapon systems worldwide, survivability of the warfighter and integrity of his platform—whether ship, aircraft or ground vehicle—is paramount. This Self-Protection subarea will produce advanced, automated active jammer technologies and associated/integrated EA/ECM techniques across the RF, EO and IR spectrums. Critically linked to the employment of the appropriate counter is the previous subarea of Threat Warning—in that it provides the accurate warning and SA *in time* to execute the optimum self-protection response. Development of automated effective, and reliable self-protection systems will free crews to concentrate on executing their assigned mission, putting the weapon on target, etc. Self-Protection technology has opportunities to make a transition at all levels of weapon system development. Specifically, these systems include advanced multi-spectral expendables, decoys, IR and RF jamming systems; and incremental upgrades to existing systems with compact, reliable, space- and weight-saving technologies (e.g., again, digital). Technology insertion will play a pivotal role toward enhancing existing systems so that they will remain effective into the 21st century.

3.11.2 Overview

3.11.2.1 Goals and Timeframes. The Self-Protection technology subarea addresses: (1) the ability to counter microwave and MMW RF threat radars via the development of advanced coherent jamming and deception technologies; and development of decoys for self-protection and angular deception of sensors; (2) laser technology to detect/perform scan analysis and jam EO and IR threat systems; improving flares in the IR, UV and RF bands which will be capable of defeating multimode or monomode threats; and (3) advanced component insertion/architectures that result in reduced size, cost and weight of active CM systems. Major goals and associated timeframes include the following:

Application/Mission	Short-term (1-2 Years)	Mid-term (3-5 Years)	Long-term (6+ Years)

Application/Mission	Short-term (1-2 Years)	Mid-term (3-5 Years)	Long-term (6+ Years)
Microwave through MMW jamming capability for ship-borne, airborne and ground platforms.	Millimeter wave power module (MMPM) initial prototype configuration.	Completion of the MMW fiber optic link and phase shifter.	Dev beamrider sensor/jammer CM.
Defeat advanced IR seekers using expendable CM and jamming.	Integrate and demo advanced IR missile warning hand-off to open-loop IR jamming.	Conduct live fire, cable car test of fiber optic coupled, multiline lasers and HPM technique (Ref. DTAP Section 3.9).	Dev and demo compact, integrated, laser-based, closed-loop IRCM capability for all large aircraft.
Laser based IRCM capability for tactical aircraft.	Phase I - ARPA deliver two lasers for the Services use.	Phase II - develop 20w, 10 - 20 kHz multiband lasers for full closed loop applications.	Expand laser bands to CO2 and CCD camera (40 % increase in jamming band).
Multi-source CM solution capable of countering present & future multi-color imaging focal plane array & non-imaging IR/EO/RF missile seekers.	Experimental evaluation of the advanced spectrally balanced two-color flare.	Flight testing of the flare.	
Defeat Advanced ASM Seekers using on board advanced transmitters and off board decoys.	Initial demo of Eager preferential decoy.	Demonstration of Advanced ECM transmitter technology.	Incorporate Advanced transmitter and decoys into AIEWS design.

3.11.2.2 Major Technical Challenges. In the basic threat engagement, to the first order, the decision to employ self-protection is linked to the Threat Warning function—the challenge being the optimal, precise selection and time of the CM [e.g., premature electromagnetic radiation from the platform only serves to highlight its presence/location to the threat; poorly timed flare ejection's will be rejected by the electronic counter countermeasures (ECCM) features of the IR missile]. This issue/challenge becomes even more critical for low observable (LO) platforms and for special operating forces (SOF) missions. In the LO, the challenge is in the development of self-protection HW, materials, electronic techniques and the digital modeling thereof which will be compatible with this class of platform. In the decoy arena, RF challenges include developing increasingly more sophisticated electronics to fit within existing dispensers at an affordable cost; enhancements to chaff technology to extend the frequency coverage; and protecting slow-moving, large cross-section ships from the ASCM. In the IR, the challenges include decoy techniques for the forecasted class of imaging seekers; development of composite flare materials which emulate the signatures of the warfighter's platform; maintaining the position of the flare/decoy in missile

seeker's field-of-view (FOV); and achieving covert effectiveness where dictated by the mission. In the RF jamming area, multiple challenges include jammer design with high transmit-receiver isolation; coherent, high fidelity jamming waveforms; reactive/retro directive capability; coordinated, time-synchronized, multiple platform response and a modular design scaleable to all platforms. In the IR/electro-optical regime, major challenges involve the radiation of multiple laser wavelengths necessary to jam a variety of threat missiles simultaneously; demonstrating small, low-cost laser pointing and tracking devices to deliver adequate multi-band laser energy in the high maneuver dynamics of combat aircraft; design and demonstrate EOCM fieldable prototype for ship self defense; tracking incoming threats via reflected laser energy or missile plume emissions; and steering IR/EO laser beams without the need for a complex, costly, stabilized gimbal platform.

3.11.2.3 Related Federal and Private Sector Efforts. DoD has the primary/sole responsibility for Self-Protection S&T within the federal government—with very little application(s) to the private sector. This subarea is supported by the IRAD investments of numerous defense industry contractors.

3.11.3 S&T Investment Strategy

In executing the Self-Protection subarea, focus is maintained on specific technology demonstrations which synergistically integrate advanced aperture, transmitter/source, coherent/digital exciter techniques <u>with</u> its companion Threat Warning functionality (as appropriate), in order that technology development in these same areas—but at the component/ functional level—can also be focused. National investments between the technology demonstrations and technology development efforts are allocated in accordance with their potential payoff to warfighting needs, affordability and their relative contribution to achieving Self-Protection goals.

3.11.3.1 Technology Demonstrations. In the near term, as recommended by the 1995 Technology Area Review and Assessment (TARA) of EW, the number one EW S&T priority is IRCM. Hence, the self-protection subarea is dominated by WE.03 and WE.09 with the goal of demonstrating advanced, laser-based IRCM technology for multiple combat platforms. "Tech demo" level programs will demonstrate affordable solutions for helicopter ("Multi-Spectral CM"), aircraft (TACAIR DIRCM ATD and Large Aircraft IRCM) and ships (proposed MATES ACTD). RF self-protection demonstrations will be conducted in accordance with this subarea's investment strategy.

3.11.3.2 Technology Development. The Service and Agency efforts in the Self-Protection subarea are divided into three classes:

RF Technology - Develop MMW systems, subsystems and power amplification/radiation chains such as MMW power module technology, LO and anti-radiation missile (ARM) CM; RF decoys and expendable vehicle technology to provide platform like decoys (kinematic fly along for aircraft, and slow moving for ships and ground based sites and platforms); Coherent RF jamming techniques and counters to synthetic aperture radars (SAR).

IR Technology - Develop IR decoys including IR materials and deployment concepts to address the decoy discrimination and imaging seeker problems. Develop

IRCM to provide capabilities to detect, analyze, jam and exploit imaging and advanced IR seekers.

EO Technology - To develop laser devices with improved frequency agility, efficiency, reliability and strength, while also reducing size, cost and weight of active CM systems.

3.11.3.3 Basic Research. Similar to Threat Warning subarea. Refer to 3.10.3.3.

3.12 EW—Mission Support

3.12.1 Warfighter Needs

As proven by Desert Storm, an effective stand-off Electronic Attack (EA) campaign against both enemy radar sensors and communication infrastructure damages his ability to determine the location and intent of our Joint Forces, and his ability to control his offensive or defensive forces. The S&T in Mission Support will significantly enhance warfighter operations by proactively separating the enemy command element from its forces by disrupting C^3 nodes/links, navigation systems, long-range, integrated air defense radars, and other electronic aids that provide battlefield/situation assessment to enemy forces. This degradation of the enemy's C^3/integrated air defense system (IADS) structure must be effectively accomplished without hindering those same elements of our own. Opportunities for transitioning the C^2W and counter-IADS Mission Support technology efforts exist in current jamming and C^3CM systems. Future systems designed for exploitation, countersurveillance communications and radar tracking will afford a fertile environment for testing and application of this technology. Also included in this subarea is the pursuit of interactive simulation which will reduce the time and cost required to develop the entire scope of EW system capabilities dealt with in Sections 3.10, 3.11 and 3.12, resulting in a faster transition to the warfighter's operational "arsenal," at affordable acquisition cost. Simulation and modeling will also result in more EW advanced systems with increased capability, as proposed modifications and performance enhancements can be tested by the S&T and user communities for effectiveness prior to development and production.

3.12.2 Overview

3.12.2.1 Goals and Timeframes. Modern battlefield commanders on both sides require information as never before - not merely information on enemy numbers, location, movement, readiness, weapons capabilities, control structures or awareness of friendly actions—but also similar information on his/her own forces and those of allies. To provide that information to friendly forces and to deny that same information to the threat commander, EW systems technology thrusts in the Mission Support technology subarea address three elements: RF Mission Support; Electronic Protection (EP); and EW Employment. Technologies provided will increase the capabilities of EW systems to (1) intercept and selectively deceive or totally disrupt enemy C^2, surveillance and weapon systems while maintaining uninterrupted friendly communication links; (2) employ automated data fusion processes to insure timely intelligence and rapid, tactical decision-making to operate inside of the enemy's decision cycle; (3) invoke modeling and simulation to investigate new and untried system architectures; (4) increase the readiness

of our forces through training on simulators using actual EW systems; and (5) exploit available threat systems to increase survivability through better knowledge of doctrine and tactics, better knowledge of weapon system capability, and increased CM effectiveness. Major goals and associated timeframes include:

Application/Mission	Short-term (1-2 Years)	Mid-term (3-5 Years)	Long-term (6+ Years)
Exploitation and jamming of mobile and digital C^3 systems	Demo significant increase in number of HF signals that can be simultaneously countered, through optimized techniques and increased wideband power generation.	Demo techniques of countering current digital communi-cations signal format.	Demo techniques for countering future digital communi-cations signal format.
Robust, all aspect Anti-ship missile CM (ASCM) simulation capability.	Add a cloud cover model to the IR predictive code for the CRUISE Missiles EW simulation.	Provide a RF/IR digital model representative of the multi-spectral environment.	
Extension of target collection range, attack and mobility of IEW Common Sensor (IEWCS).	Demo 40 % collection range exercise through UAV test.	Demo 90 % increase in precision location capability for targets outside range of IEWCS and selective jamming attacks in UAV flight test; integrate and demo with airborne IEWCS platforms.	Demo over target collection and description at over 75 % extended ranges on planned mobile digital communica-tions using UAV tethered to IEWCS.
Airborne multiple sensor fusion.	Complete the multi-INT sensor correlation with moving target indicator.	Demo advanced airborne planning algorithms and ef-fectiveness tools for multi-sensor tasking and reporting using DB to DB interfaces	Integrate SIGINT/MTI sensor cross cueing and situation displays into IEWCS and all-source analysis system (ASAS).
Develop capability to surgically counter C^2W systems with minimal fratricide.	Test communication / navigation CM capabilities against ground & airborne platforms.	Demo airborne CM against future navigation systems	
Next generation RF stand-off support jammer (SSOJ).	Dev and demo integrated MPM phased array architectures.	Dev and demo broadband, polarization agile transmit/receive architecture with single-degree beam control	Demo multi-tactical platform (include UAVs and pods) integration in full-band (decode +) configuration.

3.12.2.2 Major Technical Challenges. In the C^2W role, the principal challenge is the global spread of extremely affordable, portable, modern telecommunications technology. Their extremely complex modulation formats, multiplexing schemes and

spread spectrum coding pose severe hurdles to even the Electronic Support (ES) system in its real-time abilities to intercept, detect and ID. Given that challenge, then the EA portion of the system must accomplish "surgical" attacks on enemy C^2 and navigation aids with minimal collateral/fratricidal damage due to the commonality of frequencies used by both forces. In the high frequency (HF) communications region, resurging interest in this "comms" method imposes severe HW challenges upon the EA and ES subsystems (by virtue of the multi-meter wavelengths involved), and affordable integration thereof on a broad class of existing, operational warfighter platforms (small, *mobile* ground vehicles; airborne; and shipborne)—e.g., efficient, broadband amplifiers and antennas; and over the horizon detection schemes. The final C^2W challenge comes in a capability to correlate and combine all force sensors (active and passive) data to provide a complete tactical picture. For RF Mission Support, the challenges are two-fold: creating an architecture for an affordable, next-generation Standoff Jamming (SOJ) capability to replace the retiring, highly effective EF-111 fleet and its EA-6B companion; and proving low-cost, effective electronic enhancements to the SEAD mission.

3.12.2.3 Related Federal and Private Sector Efforts. Although EW is primarily used by DoD organizations, there are commercial activities pursuing directly related technologies. DoD EW technology efforts are complemented by industry initiatives, particularly in the advanced communications areas. The EA techniques against modern threat C^3 systems are also being applied in an EP fashion to efforts protecting our own military and commercial communications and computer networks through the development of common tool sets for information protection. DoD, law enforcement, customs and other federal organizations have been partners with the commercial sector and academia in the development of data fusion technology and data fusion systems. Industry is involved in data fusion applications running the gambit from strategic intelligence production and tactical situation awareness development to automated production, preventative maintenance and autonomous robot applications. Spin-offs from DoD work in data fusion include factory automation, advanced safety systems, multisensor diagnostic systems and earth resource management.

3.12.3 S&T Investment Strategy

In executing the Mission Support subarea, focus is maintained on specific technology demonstrations which synergistically integrate advanced antenna, processor, receiver and transmitter technologies, in order that technology development in these same areas—but at the component/functional level—can also be focused. National investments among the various technology demonstration and technology development efforts are allocated in accordance with their potential payoff to warfighting needs, affordability and their relative contribution to achieving Mission Support goals.

3.12.3.1 Technology Demonstrations. In accordance with the aforementioned TARA recommendations, the second most important area in EW S&T is C^2W. Hence, the tech demos in Mission Support depict this posture and provide incremental achievement to reach WE.24. Objectives include significant tactical battlefield information fusion and concommitant EA, countermeasures to advanced forms of navigation aids to human forces and weapon systems, ES/EA of modern network communications, and development of advanced C^2W receiver and transmitter

architectures/ components. Other Mission Support demonstrations will be conducted in accordance with this subarea's investment strategy.

3.12.3.2 Technology Development. The Service efforts in the Mission Support subarea can be divided into three classes:

RF Mission Support Technology - To develop the technology to attack the enemy C^2 and IADS network. Detection, degradation, deception and destruction are all part of the total requirement. A development goal is to provide the capability to surgically counter both communication and navigation systems by disrupting C^3 nodes and links without negatively impacting friendly users, denying war, and most particularly, operations other than war (OOTW) to avoid shared communication facilities of other nations and international humanitarian organizations.

EP Technology - To provide protection against threat EA enhancements. This portion of the EW S&T program develops necessary technology to perform vulnerability assessments to assure that U.S. weapon, C^3 and intelligence (C^3I) systems have adequate and cost effective hardening. The technology here is at a basic S&T level which is quickly transferred/transitioned to System Developers for rapid insertion of protection techniques/upgrades to our operational systems.

EW Simulation - To support detailed engineering analyses of both specific EW equipment and technologies, and computer-intensive higher order simulations are necessary to analyze all levels from one-on-one to force-on-force scenarios. Simulation visualization technologies are also needed to allow immediate, man-in-the-loop evaluation and interaction with EW scenarios.

3.12.3.3 Basic Research. Basic research efforts are underway that support this Mission Support subarea. Signal processing research in modulation characterization, fast adaptive super solution beamforming, noise reduction, adaptive direction finding algorithms and antenna size reduction using high temperature superconducting (HTS) elements directly apply to ES and EA against modern communication systems. Basic research efforts in data fusion emphasize the theoretical underpinnings of information combination and investigate promising new approaches and concepts in providing timely tactical battlefield intelligence fusion and situation assessment needed for effective EA. Investigations are being conducted in the development and evaluation of new paradigms for machine-based reasoning, advanced database management system design, optimal constraint-based resource management, and new evidence combination methodologies.

4.0. TECHNOLOGY ROADMAPS

4.1. Technology Roadmaps

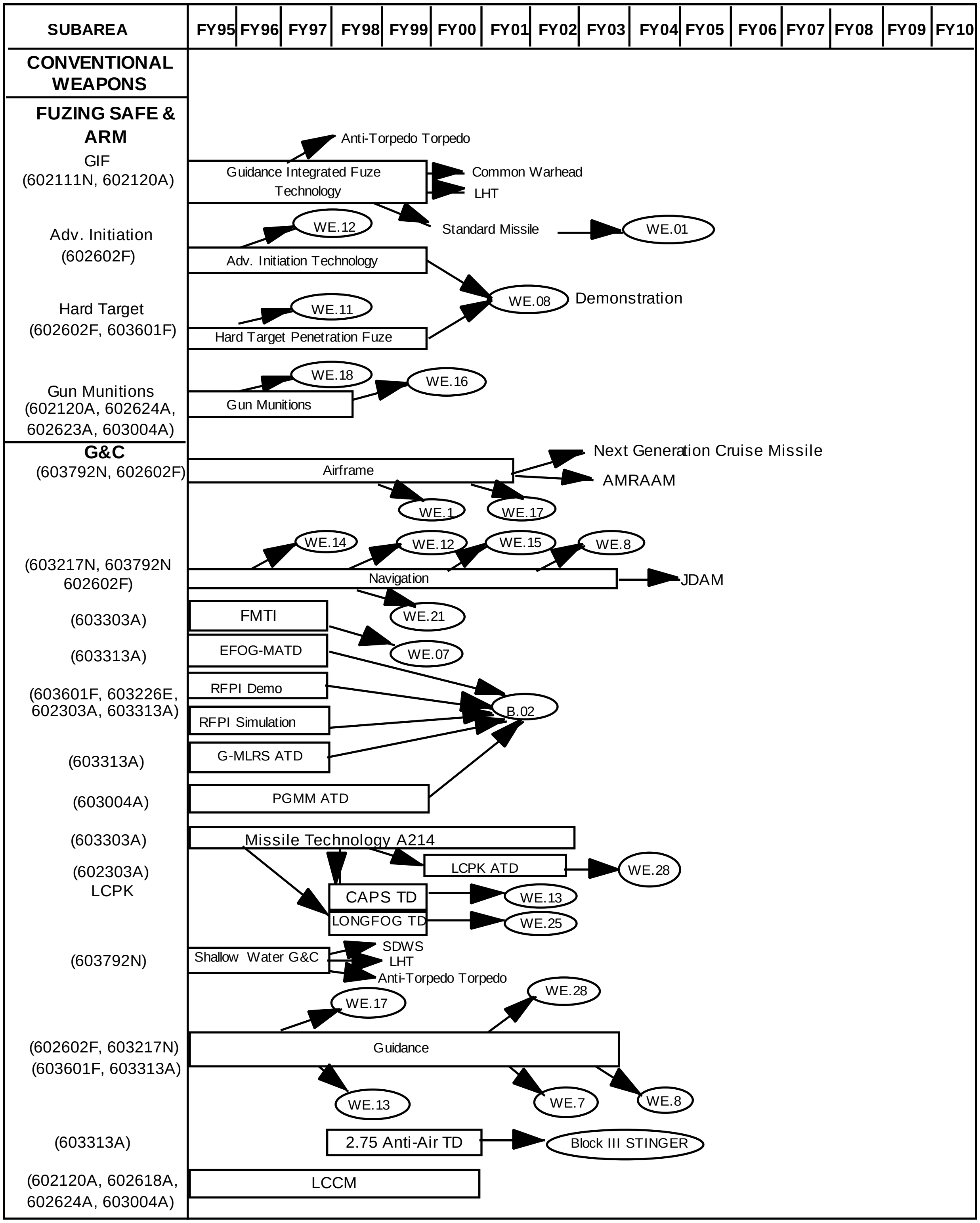


Figure X.3. Conventional Weapons Technology Roadmap

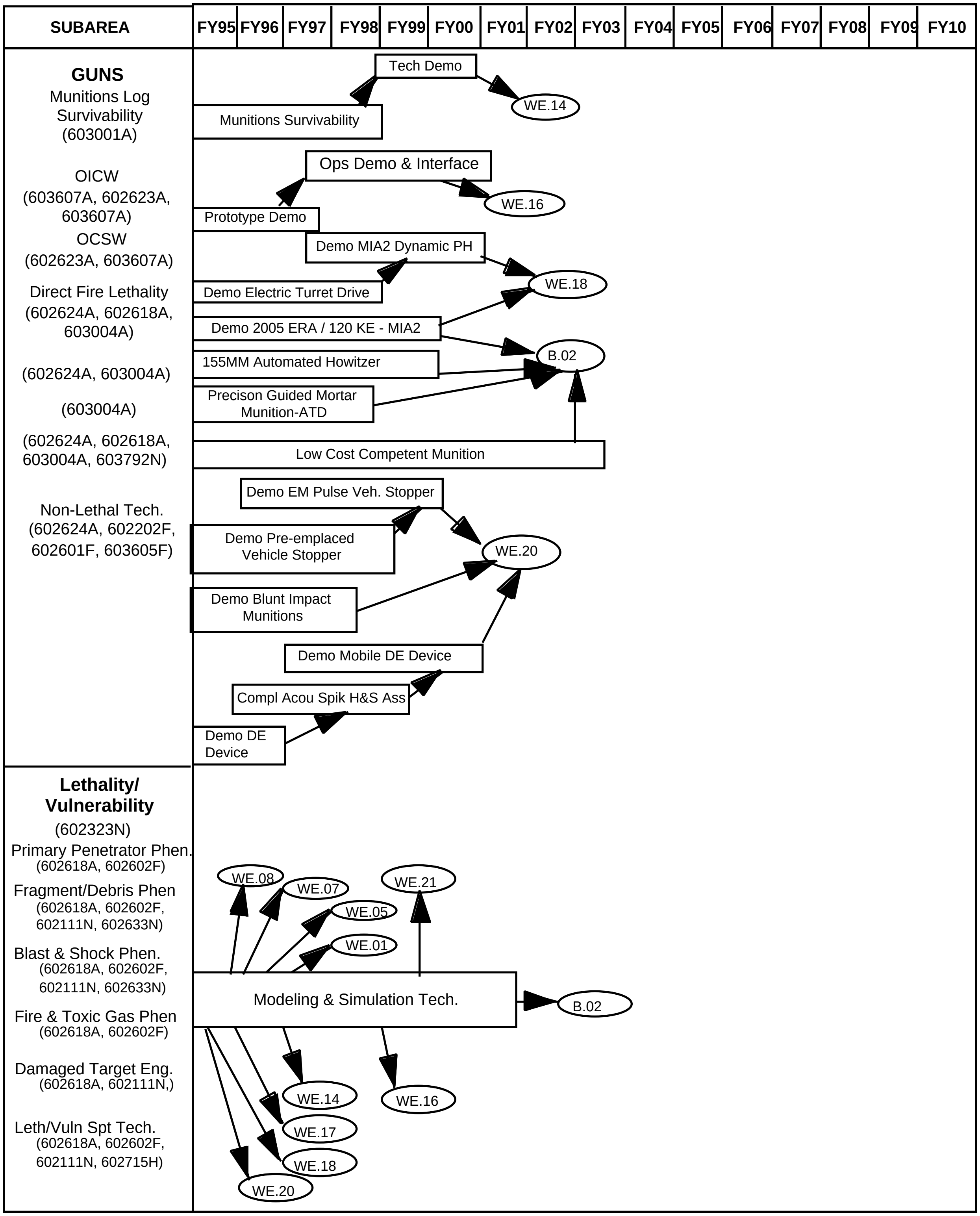


Figure X.4. Conventional Weapons Technology Roadmap

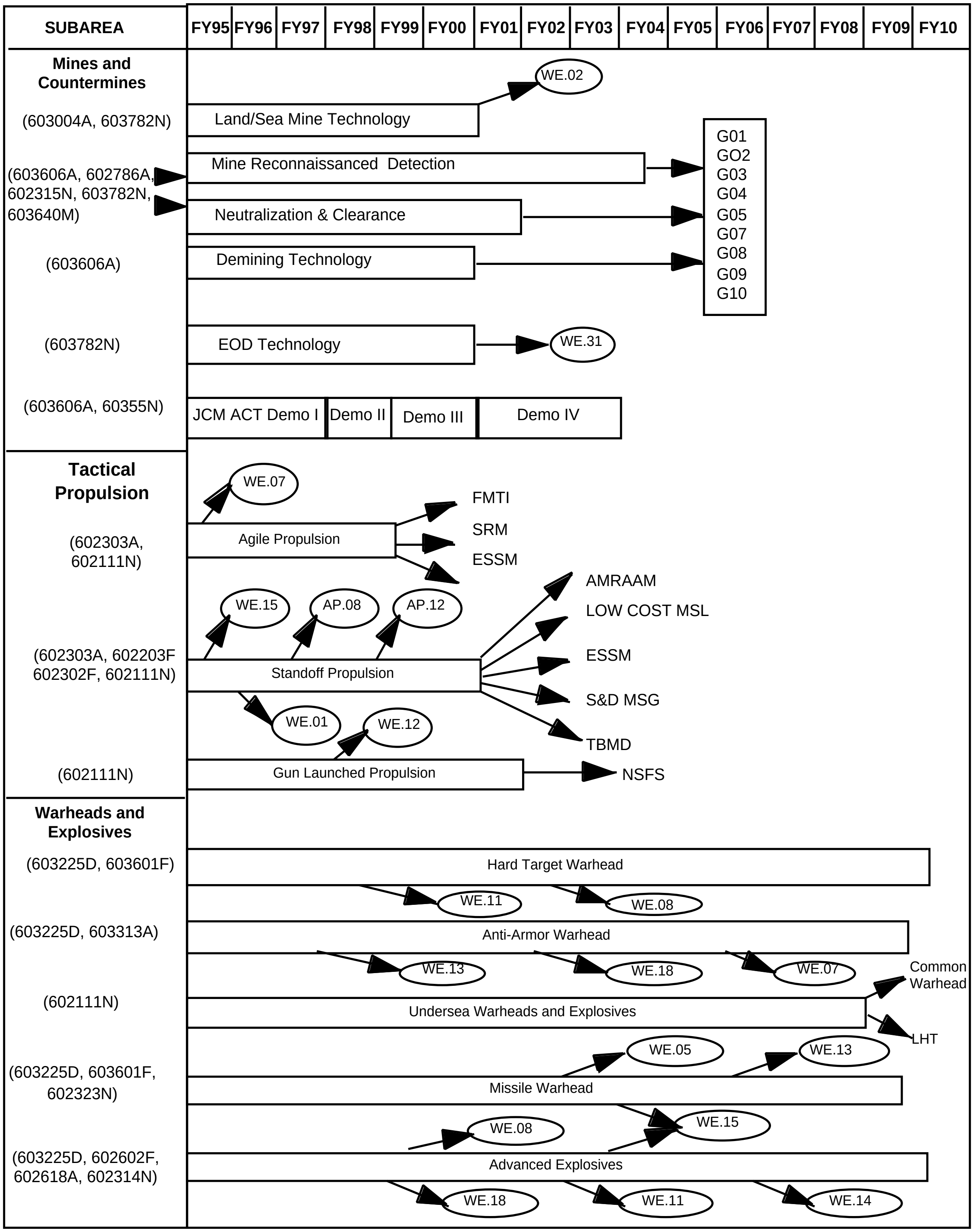


Figure X.5. Conventional Weapons Technology Roadmap

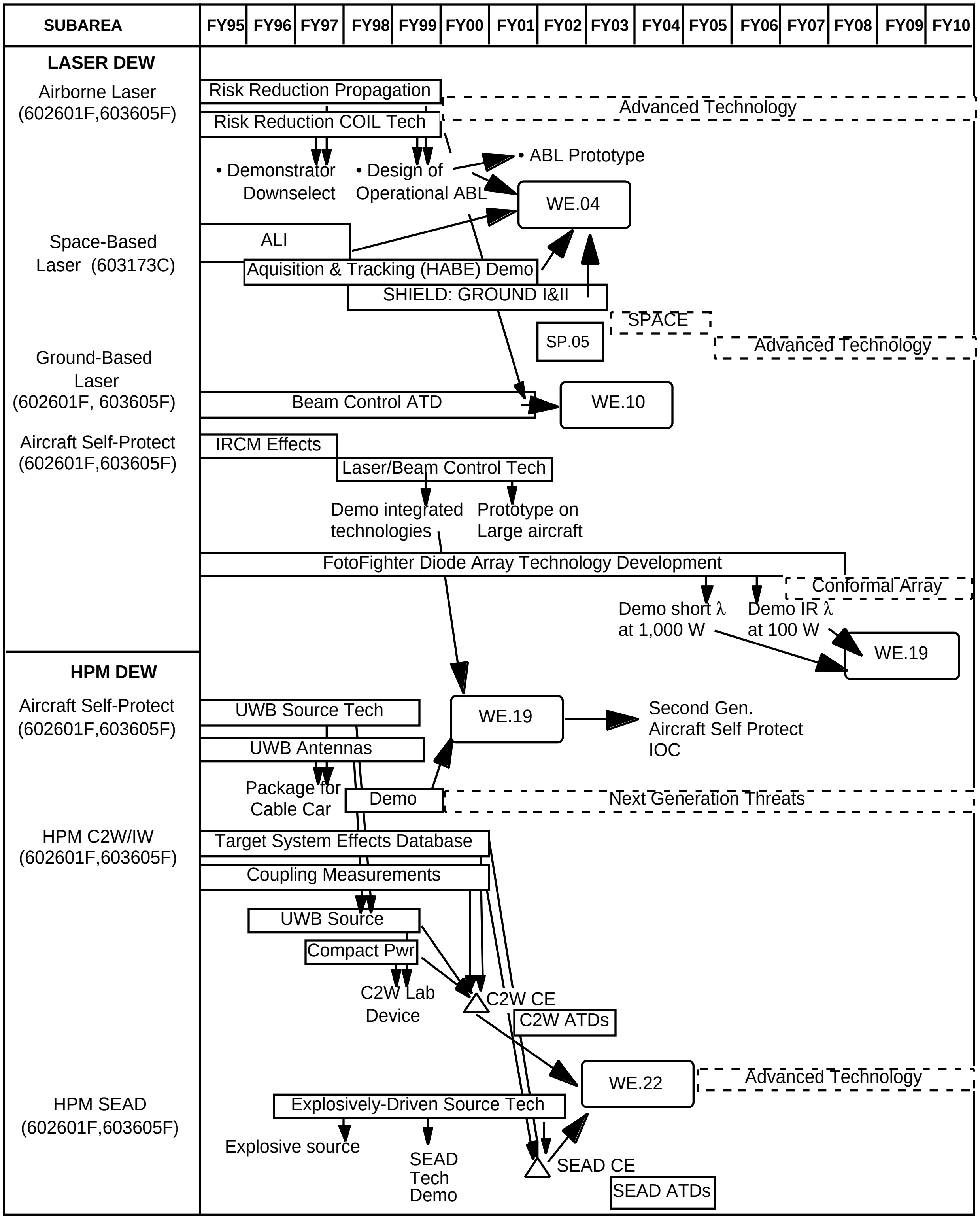


Figure X.6. Directed Energy Weapons Technology Roadmap

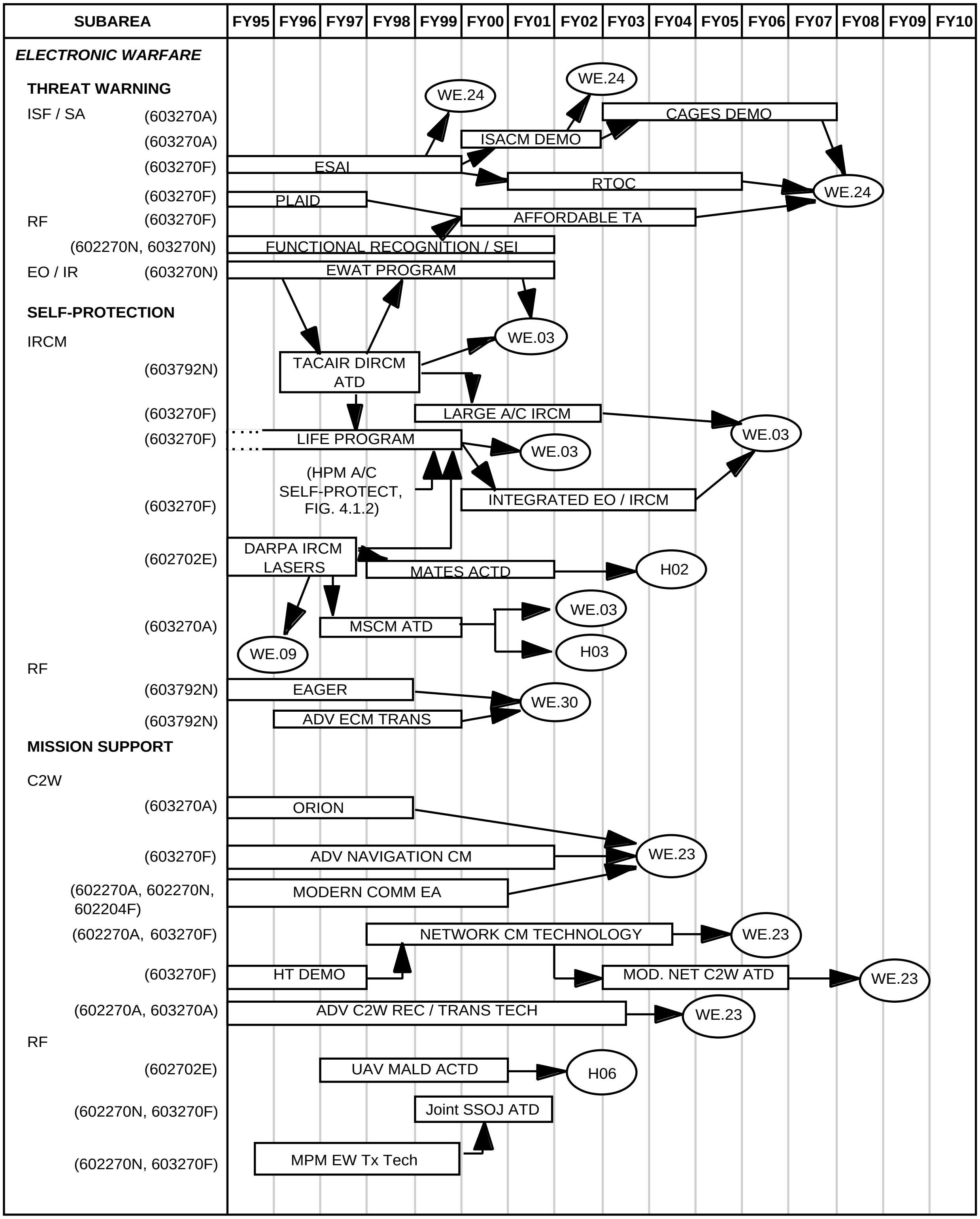


Figure X.7. Electronic Warfare Technology Roadmap

4.2. Technology Roadmap Resources ($M)

DTOs	Program Element	$ in millions					
		FY96	FY97	FY98	FY99	FY00	FY01
WE.01.04.ANF MAKE	0603792N	5.0	11.2	9.0	5.0	0	0
	0602303A	1.8	2.8	3.9	1.5	0	0
	0602601F	--	4.2	6.4	7.1	8.3	7.7
	0602602F	--	0.7	1.2	2.6	1.1	1.6
	0603302F	0.3	0.3	0.3	0.3	0.3	0.3
	0603601F	--	0.1	1.8	1.5	4.0	3.0
	0602624A	2.0	0	0	0	0	0
	DTO Total	9.1	19.3	22.6	18.0	13.7	12.6
WE.02.07.AN: LM/SM	0603004A	2.8	2.2	0	o	0	0
	0602315N	3.5	3.6	3.5	3.6	3.6	3.6
	DTO Total	6.3	5.8	3.5	3.6	3.6	3.6
WE.03.08.ANF: Combat A/C IRCM	0603270A	--	3.0	4.0	6.0	0	0
	0603270F	1.9	4.9	5.4	2.1	5.0	7.5
	0603792N	5.3	5.4	0	0	0	0
	0603270N	0.7	0.8	1.0	1.0	1.0	1.0
	DTO Total	7.9	14.1	10.4	9.1	6.0	8.5
WE.04.04.CF: Hi Pwr Laser TMD	0603605F	7.6	11.4	10.0	7.7	7.4	7.6
	0603173C	50.0	25.5	21.5	19.0	20.0	20.0
	DTO Total	57.6	36.9	31.5	26.7	27.4	27.6
WE.05.02.F: AWFT	0603601F	0.5	2.0	4.4	4.0	0.7	0
	DTO Total	0.5	2.0	4.4	4.0	0.7	0
WE.06.02.N: CCL	0603792N	5.0	0	0	0	0	0
	0603217N	--	5.0	5.0	5.0	0	0
	DTO Total	5.0	5.0	5.0	5.0	0	0
WE.07.02.A: FMTI	0603313A	19.1	9.3	1.0	4.0	19.0	23.0
	DTO Total	19.1	9.3	1.0	4.0	19.0	23.0
WE.08.02.F: MMT Guided Flight Test	0603601F	7.0	2.0	0.1	2.5	3.0	3.0
	DTO Total	7.0	2.0	0.1	2.5	3.0	3.0
WE.09.08.E: DARPA/Tri-Service Laser	0602702E	3.5	3.5	0	0	0	0
	DTO Total	3.5	3.5	0	0	0	0

Figure X.8. Weapons Technology Roadmap Resources
TOTALS MAY NOT AGREE DUE TO ROUNDING

DTOs	Program Element	$ in millions					
		FY96	FY97	FY98	FY99	FY00	FY01
WE.10.08.F: GBL ASAT	0603605F	17.0	14.0	13.5	12.6	10.4	10.5
	DTO Total	17.0	14.0	13.5	12.6	10.4	10.5
WE.11.12.D: AUP	0603160D	6.3	4.3	0	0	0	0
	DTO Total	6.3	4.3	0	0	0	0
WE.12.02.ANFH: Anti-Jam GPS Inertial Competent Mun's	0603792N	6.0	10.7	7.9	5.4	0	0
	0602120A	0.2	0.3	0.3	0.4	0.4	0
	0602624A	2.8	2.9	2.0	2.0	1.8	0
	0602618A	1.4	1.3	1.1	1.1	1.1	0
	0603004A	--	1.9	4.4	4.1	3.6	0
	0603601F	2.9	2.8	3.1	0	0	0
	0602715H	2.9	2.7	0.9	0	0	0
	DTO Total	16.2	22.6	19.7	13.0	6.9	0
WE.13.02.A: CAPS	0603313A	--	1.9	1.9	2.4	0.5	0
	0602303A	0.4	0.4	0	0	0	0
	0602618A	1.1	1.9	3.1	1.8	0	0
	DTO Total	1.5	4.2	5.0	4.2	0.5	0
WE.14.11.A: Munit's Logistics Survivability	0603001A	1.0	2.9	2.8	4.7	6.2	0
	DTO Total	1.0	2.9	2.8	4.7	6.2	0
WE.15.02.N: Low Cost Msl	0603792N	--	4.4	6.1	4.5	0	0
	DTO Total	--	4.4	6.1	4.5	0	0
WE.16.05.A: OICW	0603607A	3.7	1.9	3.3	2.9	0	0
	DTO Total	3.7	1.9	3.3	2.9	0	0
WE.17.02.F: Hammerhead	0603601F	4.9	5.0	3.0	3.0	0	0
	DTO Total	4.9	5.0	3.0	3.0	0	0
WE.18.02.A: Direct Fire Lethality	0602624A	1.0	1.1	1.5	0.7	0	0
	0602618A	2.3	3.0	0.8	0	0	0
	0603004A	2.5	3.6	7.7	8.2	6.2	0
	DTO Total	6.8	7.7	10.0	8.9	6.2	0
WE.19.08.F: Aircraft Self-Protect	0602601F	6.0	8.8	12.3	10.7	5.2	5.1
	0603605F	12.5	9.5	9.2	10.3	8.0	9.3
	DTO Total	18.5	18.3	21.5	21.0	13.2	14.4
WE.20.02.AF: Non-Lethal Tech	0602202F	0.5	0.5	0.5	0.4	0.4	0.4
	0602601F	0.5	0	0	0	0	0
	0603605F	--	0.5	0.5	0.5	0.5	0.5
	DTO Total	1.0	1.0	1.0	0.9	0.9	0.9

Figure X.8. Weapons Technology Roadmap Resources (cont.)
TOTALS MAY NOT AGREE DUE TO ROUNDING

DTOs	Program Element	$ in millions					
		FY96	FY97	FY98	FY99	FY00	FY01
WE.21.02.NE:	0603226E	11.9	10.5	15.0	16.6	11.1	28.0
Fiber Optic Gyro	0603217N	--	3.5	4.5	5.0	0	0
Navigation	0603792N	2.0	0	0	0	0	0
	DTO Total	13.9	14.0	19.5	21.6	11.1	28.0
WE.22.09.F:	0602601F	8.4	8.3	8.7	10.4	13.7	13.9
HPM C2W/IW	0603605F	5.1	4.8	4.7	6.5	7.3	7.3
	DTO Total	13.5	13.1	13.4	16.9	21.0	21.2
WE.23.08.ANF:	0602270A	2.9	2.5	2.5	2.9	0	0
Network C^2W	0603270A	0.4	1.2	1.1	1.2	0	0
	0602270N	0.5	0.7	0.7	0.7	0.8	0.8
	0603270F	2.8	0.7	1.1	2.8	3.5	1.7
	0602204F	0.8	0.8	0.8	0.8	0.8	0.8
	DTO Total	7.4	5.9	6.2	8.4	5.1	3.3
WE.24.08.ANF:	0602270A	1.5	2.7	2.9	3.1	3.3	0
Situation	0603270A	0.6	0.6	0.6	2.0	2.0	0
Assessment	0602270N	2.3	3.2	3.2	3.4	3.4	3.5
	0603270N	3.4	4.2	4.2	4.3	4.4	4.6
	0603270F	8.9	6.4	3.2	0.9	0	3.1
	0602270A	3.0	3.1	3.1	3.4	0	0
	DTO Total	19.7	20.2	17.2	17.1	13.1	11.2
WE.25.02.A: Multimode Air Frame Tech. Demonstration	0602303A	3.4	3.6	1.2	0	0	0
	DTO Total	3.4	3.6	1.2	0	0	0
WE.26.02.N: Cruise Msl	0603792N	5.0	5.7	5.5	6.1	4.5	0
	DTO Total	5.0	5.7	5.5	6.1	4.5	0
WE.27.02.N:	0603217N	--	3.7	4.9	4.2	0	0
CE Ball Joint	0603792N	2.0	0	0	0	0	0
	DTO Total	2.0	3.7	4.9	4.2	0	0
WE.28.02.A: LCPK 2.75	0602303A	0.5	1.2	1.2	0	0	0
	DTO Total	0.5	1.2	1.2	0	0	0
WE.29.02.N: ATT	0603792N	--	4.0	5.0	5.0	0	0
	DTO Total	--	4.0	5.0	5.0	0	0
WE.30.08.N: Adv ECM Xmitter for Ship Defense.	0603792N	8.5	10.0	4.0	0	0	0
	DTO Total	8.5	10.0	4.0	0	0	0
WE.31.02N: EOD	0602315N	5.0	5.2	5.2	5.2	5.2	5.3
	DTO Total	5.0	5.2	5.2	5.2	5.2	5.3

Figure X.8. Weapons Technology Roadmap Resources (concluded)

TOTALS MAY NOT AGREE DUE TO ROUNDING

WEAPONS
ACRONYMS

21CLW	21st Century Land Warrior
A/C	Aircraft
AAM	Air-to-Air Missile
ABL	Airborne Laser
ACTD	Advanced Concept Technology Demonstration
AEIWS	Advanced Integrated ECM System
AGMS	Air-to-Ground Missile System
AGTFT	Anti-Jamming GPS Technology Flight Test
AHMCM	Anti-Helicopter Mine Countermeasure
AIEWS	Advanced Integrated EW System
AJ	Anti-Jamming
ALI	Alpha/LAMP Integration
ALISS	Advanced Lightweight Influence Sweep System
ALMDS	Airborne Laser Mine Detection System
ALPHA	HF Chemical Laser for Space Applications
AMFT	Anti-Materiel Warhead Flight Test
AMM	Anti-Materiel Munition
ARDEC	Army Research Development and Engineering Center
ARL	Army Research Laboratory
ARM	Anti-Radiation Missile
ARPA	Advanced Research Projects Agency
ASAS	All-Source Analysis System
ASAT	Anti-Satellite
ASCM	Anti-Ship Cruise Missile
ASM	Air-to-Surface Missile
ASMT	Air Superiority Missile Technology
ASTAMIDS	Airborne Standoff Minefield Reconnaissance and Detection System
ASUW	Anti-Surface Ship Warfare
ASW	Anti-Submarine Warfare
ATD	Advanced Technology Demonstration
ATIRCM	Advanced Threat Infrared Countermeasures
ATIRCM-CMWS	Advanced Threat IRCM - Common Missile Warning System
ATP	Acquisition, Tracking, and Pointing
ATR	Automatic Target Recognition
ATT	Anti-Torpedo Torpedo
AUP	Advanced Unitary Penetrator
AWFT	Anti-Material Warhead Flight Test
BAMB	Bending Annular Missile Body
BDA	Battle Damage Assessment
BMD	Ballistic Missile Defense
BPI	Boost Phase Intercept
BRP	Basic Research Plan
C^2	Command and Control
C^2W	Command and Control Warfare
C^3	Command, Control and Communications
C^3CM	Command, Control and Communications Countermeasures
C^3I	Command, Control, Communications and Intelligence
CAD	Computer Aided Design
CADS	Containerized Ammunition Distribution System
CAINS	Carrier Aircraft Inertial Navigation Systems
CAPS	Counter Active Protection System
CCD	Charge Coupled Device
CCL	Concentric Canister Launcher
CE	Critical Experiment
CIMMD	Close-In Man-Portable Mine Detector
CM	Countermeasures
CMWS	Common Missile Warning System
COBRA	Coastal Battlefield Reconnaissance and Analysis
COIL	Chemical Oxygen-Iodine Laser (lases at 1.3 ym)

COTS	Commercial-off-the-Shelf
CPK	Countermine Protection Kit
EFOGM	Extended Fiber Optic Guided Missile
CW	Conventional Weapons
DEW	Directed Energy Weapons
DF	Direction Finding
DFMA	Design for Manufacturability and Assembly
DIRCM	Directed Infrared Countermeasures
DNA	Defense Nuclear Agency
DoD	Department of Defense
DOE	Department of Energy
DOF	Degree of Freedom
DRFM	Digital Radio Frequency Memory
DSP	Digital Signal Processing
DTO	Defense Technology Objective
EA	Electronic Attack
ECCM	Electronic Counter Countermeasures
ECM	Electronic Countermeasures
EFP	Explosively Formed Projectile
EKV	Exoatmospheric Kill Vehicle
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EMD	Engineering and Manufacturing Development
EME	Electromagnetic Effects
EMI	Electromagnetic Interference
EN	Explosive Neutralization
EO	Electro-Optic
EOCM	EO Countermeasure
EOD	Explosive Ordinance Disposal
EP	Electronic Protection
EPA	Environmental Protection Agency
ERA	Explosive Reactive Armor
ERGM	Extended Range Guided Missile
ES	Electronic Support
ESM	Electronic Support Measure
ES SPO	Electronic Systems Center Systems Program Office
ETC	Electro-Thermal-Chemical
EW	Electronic Warfare
FMBT	Future Main Battle Tank
FMTI	Future Missile Technology Integration
FOC	Full Operational Capability
FOTT	Follow-on-to TOW
FOV	Field-of-View
F/S&A	Fuze/Safe & Arm
GBL	Ground Based Laser
G&C	Guidance and Control
GGP	GPS Guidance Package
GIF	Guidance Integrated Fuzing
GN&C	Guidance, Navigation and Control
GP	Guided Projectile
GPS	Global Positioning System
HABE	High Altitude Balloon Experiments
HF	High Frequency
HF	Hydrogen Fluoride (lases at 2.8 µm)
HIMARS	High Mobility Artillery Rocket Systems
HTS	High Temperature Superconducting
HPM	High-Power Microwave
HTSF	Hard Target Smart Fuze
HW	Hardware
HWIL	Hardware-In-The-Loop
IADS	Integrated Air Defense System
ID	Identification
IEW	Intelligence Electronic Warfare
IEWCS	Integrated Electronic Warfare Common Sensor
IFF	Identify Friend or Foe
IFOGS	Interferometric Fiber Optic Gyroscope
IIR	Imaging Infrared
IMF	Intelligent Minefield
IMU	Inertial Measurement Unit
INS	Inertial Navigation System
IR	Infrared
IR&D	Independent Research and Development
IRCM	Infrared Countermeasures
IRFPA	IR Focal Plane Array
IRST	Infrared Search/Track
IW	Information Warfare
JAWS	Joint Advanced Weapons System
JIC	Joint Intelligence Center
J/S	Jam-to-Signal
JAMC	Joint Amphibious Mine Countermeasure
JDAM	Joint Direct Attack Munition

JSFWC	Joint Staff Future Warfighting Capabilities
KKV'S	Kinetic Kill Vehicle
L/V	Lethality/Vulnerability
LAC	Large Aircraft
LADAR	Laser Radar
LAMP	Large Aperture Mirror Program
LCCM	Low Cost Competent Munitions
LCPK	Low Cost Precision Kill
LEO	Low Earth Orbit
LHT	Lightweight Hybrid Torpedo
LM/CM	Land Mines Countermine
LO	Low Observable
LOCAAS	Low Cost Anti-Armor Submunition
LODE	Large Optics Demonstration Experiment
LONGFOG	Long Range Fiber Optic Guided Missile
LOSAT	Line-of-Sight Anti-Tank
L&V	Lethality and Vulnerability
MAKE	Missile Agility/Kinematic Enhancement
MANPAD	Man-Portable Air Defense
MATES	Multiband ASMD Tactical EW System
MCM	Mine Countermeasures
MCMIA	MCM Integration and Automation
MEMS	Micro Electro Mechanical Systems
MFOM	MLRS Family of Missiles
MGR	Miniature GPS Receiver
MHK	Mine Hunter Killer
MICOM	Missile Command
MIMU	Miniature Inertial Measurement Unit
MITL	Man-In-The-Loop
MLRS	Multiple Launch Rocket System
µm	micrometers (or microns), 1 µm = 10^{-6} meters
MMIC	Microwave Monolithic Integrated Circuits
MMPM	Millimeter Wave Power Module
MMT	Miniaturized Munition Technology
MMW	Millimeter Wave
MOU	Memorandum of Understanding
MOUT	Military Operations in Urban Terrain
M&S	Modeling and Simulation
MSL	Missile
MSMD	Multi-Sensor Mine Detection
MTBF	Mean Time Between Failure
MTI	Moving Target Indicator
MWS	Missile Warning System
NCTR	Non-Cooperative Target Recognition
NMD	National Missile Defense
NMI/nmi	Nautical Miles
NTM	National Technical Means
NSFS	Naval Surface Fire Support
OCSW	Objective Crew Serviced Weapons
OICW	Objective Individual Combat Weapon
ONR	Office of Naval Research
OOTW	Operations Other Than War
ORSMC	Off-Route Smart Mine Clearance
P^3I	Pre-Planned Product Improvement
Pd	Probablity of detecton
Pfa	Probability of false alarm
PGM	Precision Guided Munition
PL/LI	Phillips Laboratory Lasers and Imaging
PL/WS	Phillips Laboratory Advanced Weapons and Survivability
PRF	Pulse Repetition Frequency
RAMICS	Rapid Airborne Mine Clearance System
RECO	Remote Control
RF	Radio Frequency
RFPI	Rapid Force Projection Initiative
RJC	Reaction Jet Control
RLG	Ring Laser Gyroscope
RMS	Remote Minehunt System
RTIC	Real-Time Information in the Cockpit
RTOC	Real-Time Information Out of The Cockpit
RTSMP	Real-Time Symmetric Multi-Processing
RV	Reentry Vehicle
RWR	Radar Warning Receiver
S&T	Science and Technology
SA	Situation Assessment
SAM	Surface-to-Air Missile
SAR	Synthetic Aperture Radar
SBL	Space-Based Laser
SDWS	Submarine Defensive Warfare
SEAD	Suppression of Enemy Air Defense
SEI	Specific Emitter Identification

SIGINT	Signal Intelligence
SLMM	Submarine Launched Mobile Mine
SM/CM	Sea Mine Countermeasure
SOF	Special Operations Forces
SOJ	Support/Stand-off Jamming
SOR	Starfire Optical Range
SURVIAC	Survivability Vulnerability Information Anaysis Center
SW	Software
TACAIR	Tactical Aircraft
TACAWS	The Army's Combined Arms Weapon Systems
TARA	Technology Area Review and Assessment
TBM	Tactical Ballistic Missile
TD	Technology Demonstration
TMD	Tactical Missile Defense or Theater Missile Defense
TOW	Tube Launched Optically Guided Weapon
TVC	Thrust Vector Control
TWT	Traveling-Wave Tube
UAV	Unmanned Aerial Vehicle
USSOCOM	US Special Operations Command
UV	Ultraviolet
UWB	Ultra-Wide-Band
VHSIC	Very High Speed Integrated Circuit
VIP	Very Important Person
VMMD	Vehicle Mounted Mine Detector
VSW	Very Shallow Water
W	Watt
WL	Wright Laboratory
WSC	Warfighting Support Center

RESOURCE FUNDING

DEFENSE TECHNOLOGY AREA PLAN (DTAP) FUNDING $ in thousands						
	FY1996	**FY1997**	**FY1998**	**FY1999**	**FY2000**	**FY2001**
Air Platforms	360,387	393,268	388,683	375,179	392,742	410,954
CB Defense and Nuclear	208,321	188,953	205,973	205,717	197,993	200,433
Info Systems and Tech	1,252,549	1,533,831	1,597,506	1,566,122	1,540,161	1,530,414
Ground Vehicles and Watercraft	334,828	254,679	248,352	321,589	369,805	396,878
Materials/Processes	987,234	724,185	740,771	749,876	733,799	737,507
Biomedical	397,139	266,890	257,030	315,149	367,311	401,139
Sensors and Electronics	1,113,685	1,003,904	1,026,356	1,089,983	1,129,010	1,184,259
Space Platforms	191,864	131,348	141,508	149,369	157,690	166,105
Human Systems	315,298	255,194	262,796	264,367	266,505	258,274
Weapons	1,172,219	1,171,359	1,310,689	1,299,617	1,267,366	1,258,897
Total	6,333,524	5,923,611	6,179,664	6,336,968	6,422,383	6,544,860

DEFENSE TECHNOLOGY AREA PLAN (DTAP) FUNDING $ in thousands						
	FY1996	FY1997	FY1998	FY1999	FY2000	FY2001
AIR PLATFORMS						
Aircraft Power	17,972	17,643	21,704	22,325	23,070	23,961
Fixed Wing Vehicle	152,175	196,585	170,168	136,071	144,535	150,335
High Speed Prop and Fuels	42,730	27,800	36,038	33,787	34,050	36,288
IHPTET	121,712	129,038	129,174	133,279	136,406	142,382
Rotary Wing Vehicle	25,798	22,202	31,599	49,717	54,681	57,988
Subarea Total	360,387	393,268	388,683	375,179	392,742	410,954
DTO Total	316,600	361,000	333,500	320,900	333,500	328,300
CHEMICAL/BIOLOGICAL DEFENSE AND NUCLEAR						
C/B Decontamination	20,249	21,009	24,324	21,908	19,721	18,648
C/B Detection	36,199	28,582	23,211	17,958	6,549	5,778
C/B Modeling and Simulation	6,256	2,651	2,998	3,462	3,887	3,954
C/B Protection	12,086	12,503	11,418	11,831	14,163	15,136
Scientific and Operational Computing	14,392	14,087	15,508	17,345	17,116	17,443
Systems Effects and Survivability	43,363	37,105	41,426	44,721	49,039	52,342
Test and Simulation Technology	47,057	42,153	48,525	46,071	43,044	41,336
Warfighter Support	28,719	30,863	38,563	42,421	44,474	45,796
Subarea Total	208,321	188,953	205,973	205,717	197,993	200,433
DTO Total	130,700	121,600	137,700	130,600	135,600	136,900
INFORMATION SYSTEMS AND TECHNOLOGY						
Computer-Based Tech	363,187	697,518	678,344	638,581	631,013	627,646
Decision Making	320,454	320,946	344,823	367,775	369,426	361,762
Info Management and Distribution	177,114	184,005	220,445	183,862	190,546	175,726
Model and Simulation Technology	153,446	137,873	145,313	151,197	139,238	145,484
Seamless Communications	238,348	193,489	208,581	224,707	209,938	219,796
Subarea Total	1,252,549	1,533,831	1,597,506	1,566,122	1,540,161	1,530,414
DTO Total	726,300	763,200	851,200	862,500	920,900	947,200
GROUND VEHICLES AND WATERCRAFT						
Ground Vehicles	164,399	126,084	109,113	145,457	187,766	198,282
Submarines	68,885	50,542	52,151	69,640	77,860	77,972
Surface Combatants	89,067	65,803	74,213	89,493	84,001	99,628
Unmanned Undersea Vehicles	12,477	12,250	12,875	16,999	20,178	20,996
Subarea Total	334,828	254,679	248,352	321,589	369,805	396,878
DTO Total	149,500	163,100	133,700	140,800	130,500	132,100
MATERIALS/PROCESSES						
Advanced Industrial Practices	92,531	109,168	107,514	103,358	106,538	109,489
Civil Engineering	33,882	19,203	21,100	22,104	23,563	30,275
Environmental Quality	195,101	116,675	141,021	177,575	202,537	232,526
M&P for Surv, Life Ext, and Afford	587,480	400,499	389,130	359,589	313,196	276,444
Manufacturing and Engineering	1,313	1,109	1,155	1,135	1,140	1,150
Mfg Processing and Fabrication	55,859	54,880	56,167	59,165	60,450	60,581
Military Structural and Propulsion	21,068	22,651	24,684	26,950	26,375	27,042
Subarea Total	987,234	724,185	740,771	749,876	733,799	737,507
DTO Total	500,500	458,800	473,500	407,700	397,900	390,700

DEFENSE TECHNOLOGY AREA PLAN (DTAP) FUNDING
$ in thousands

BIOMEDICAL						
Combat Casualty Care	85,216	90,599	94,039	92,058	86,514	86,814
Infectious Disease of Military	83,199	42,221	44,762	100,499	163,200	194,713
Ionizing Radiation Bioeffects	6,986	6,071	6,133	6,581	6,742	6,848
Medical Biological Defense	21,130	29,567	33,341	33,066	26,859	27,372
Medical Chemical Defense	25,907	2 1,646	23,202	24,664	24,508	25,010
Military Operational Medicine	173,391	75,961	54,694	57,293	58,624	59,540
Military Dentistry	1,310	825	859	988	864	842
Subarea Total	397,139	266,890	257,030	315,149	367,311	401,139
DTO Total	85,300	79,600	85,000	93,200	100,400	106,000
SENSORS AND ELECTRONICS						
Acoustic Sensors	101,409	90,225	97,933	108,635	119,281	121,703
Automatic Target Recognition	76,061	75,703	78,387	82,380	84,257	86,676
Electro-Optic Sensors	99,370	106,879	107,959	118,815	117,207	112,748
Electro-Optics	93,410	72,433	80,402	87,314	95,937	92,693
Electronic Materials	18,096	6,798	7,137	7,657	7,662	7,833
Electronics Integration	118,431	108,389	116,933	127,666	119,508	131,183
Integrated Platform Electronics	336	696	964	1,248	1,720	2,084
Lower Atmosphere	54,259	45,988	46,544	53,191	54,839	57,153
Microelectronics	111,915	77,333	79,407	98,681	104,442	120,926
Ocean Environment	53,096	37,462	41,225	46,813	47,320	51,252
Radar Sensors	267,895	270,695	250,679	234,088	248,005	268,534
Radio Frequency Components	80,449	74,939	81,972	85,758	90,588	92,361
Space/Upper Atmosphere	36,323	33,021	33,281	34,066	34,773	35,565
Terrestrial Environment	2,635	3,345	3,533	3,671	3,470	3,547
Subarea Total	1,113,685	1,003,904	1,026,356	1,089,983	1,129,010	1,184,259
DTO Total	721,600	712,700	780,000	807,400	726,700	716,300
SPACE PLATFORMS						
Astronics	11,864	2,083	2,487	2,496	2,675	2,565
Boost Propulsion	54,264	44,955	44,745	47,399	49,567	51,725
Guidance, Navigation, and Control	6,371	5,638	8,392	6,403	9,184	10,332
Satellite Propulsion	28,803	33,185	35,052	39,121	44,872	47,853
Spacecraft Power	34,682	27,142	31,834	32,973	35,836	36,361
Structures	1,139	1,105	1,841	2,599	3,222	4,020
Survivability	31,021	5,408	5,209	5,490	5,336	5,427
Thermal Management	23,720	11,832	11,948	12,888	6,998	7,822
Subarea Total	191,864	131,348	141,508	149,369	157,690	166,105
DTO Total	90,500	94,300	98,400	104,900	105,800	104,400

HUMAN SYSTEMS						
Design Integration	6,903	7,625	6,965	5,531	5,577	5,798
Individual Survivability	53,867	36,392	49,113	52,194	59,669	44,135
Info Management and Display	57,683	45,909	34,870	23,955	19,048	19,891
Life Support	31,355	33,341	33,084	34,477	35,787	38,062
Manpower and Personnel	12,183	12,054	12,779	14,322	14,997	15,277
Performance Aiding	38,539	35,929	36,764	39,409	40,860	43,111
Sustainability	40,443	0	0	0	0	0
System Supportability	36,877	39,632	40,836	43,595	45,732	46,702
Training	37,448	44,312	48,385	50,884	44,835	45,298
Subarea Total	315,298	255,194	262,796	264,367	266,505	258,274
DTO Total	104,800	106,600	98,990	78,000	58,500	56,000

WEAPONS						
Fuzing/Safe and Arm	19,754	24,496	25,770	25,378	23,162	19,654
Guidance and Control	295,039	293,417	352,011	319,955	290,685	299,541
Guns	81,184	77,615	81,441	94,945	93,692	105,525
High Power Microwave Weapons	37,121	33,110	33,952	35,052	36,566	37,582
High Power Laser Weapons	172,420	117,209	128,606	127,243	127,749	133,000
Lethality and Vulnerability	23,163	22,226	26,515	30,005	32,033	30,212
Mines/Countermines	126,282	117,982	119,961	136,321	140,364	137,233
Mission Support	244,088	289,020	316,353	332,793	337,887	327,959
Self Protection	24,780	29,865	35,215	35,610	29,002	26,496
Tactical Propulsion	18,708	29,903	48,396	34,957	24,791	13,200
Threat Warning	42,767	49,054	51,491	48,440	45,587	40,576
Warheads and Explosives	86,913	87,462	90,978	78,918	85,848	87,919
Subarea Total	1,172,219	1,171,359	1,310,689	1,299,617	1,267,366	1,258,897
DTO Total	268,800	270,800	247,700	233,100	175,000	173,100